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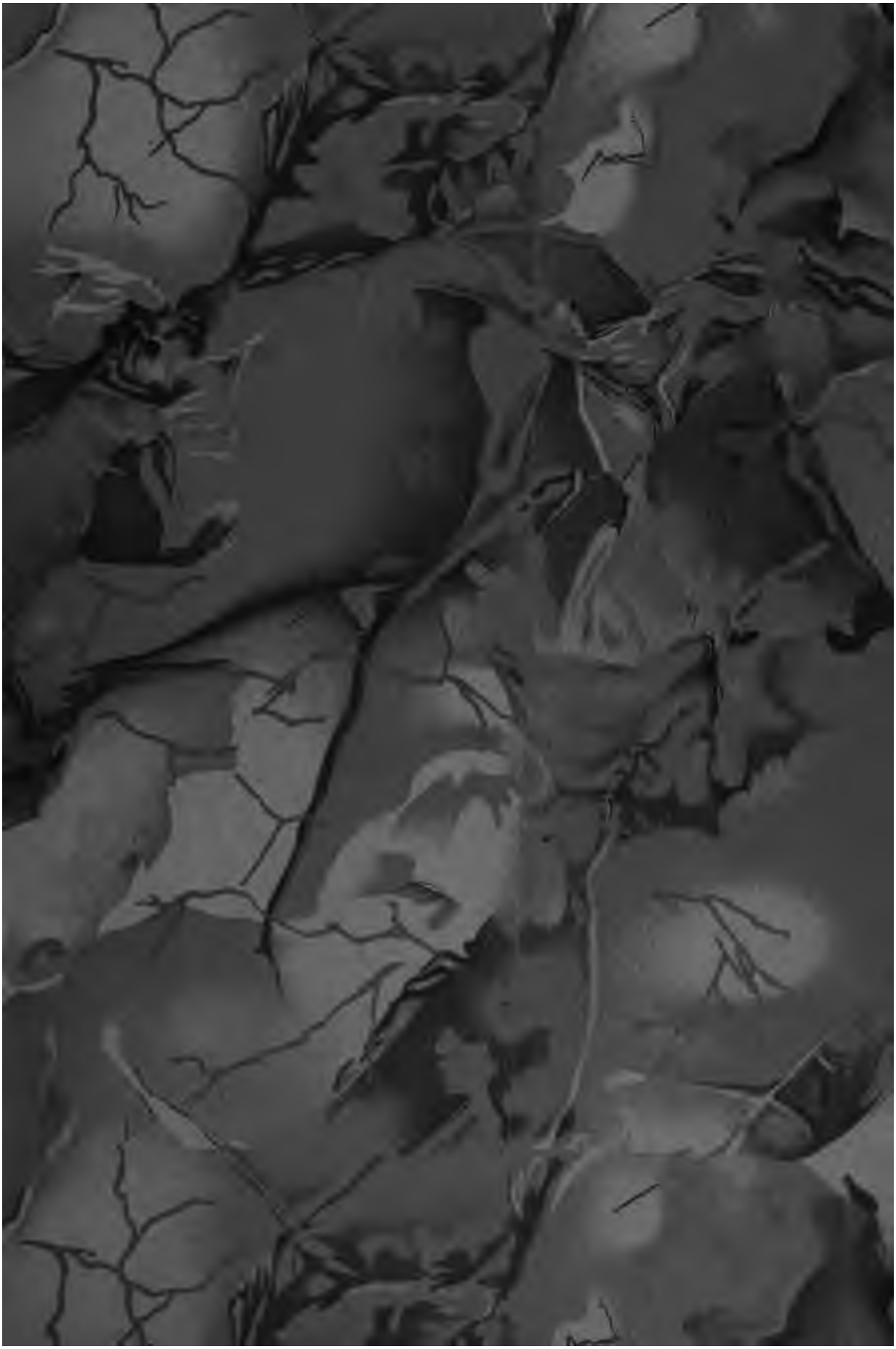

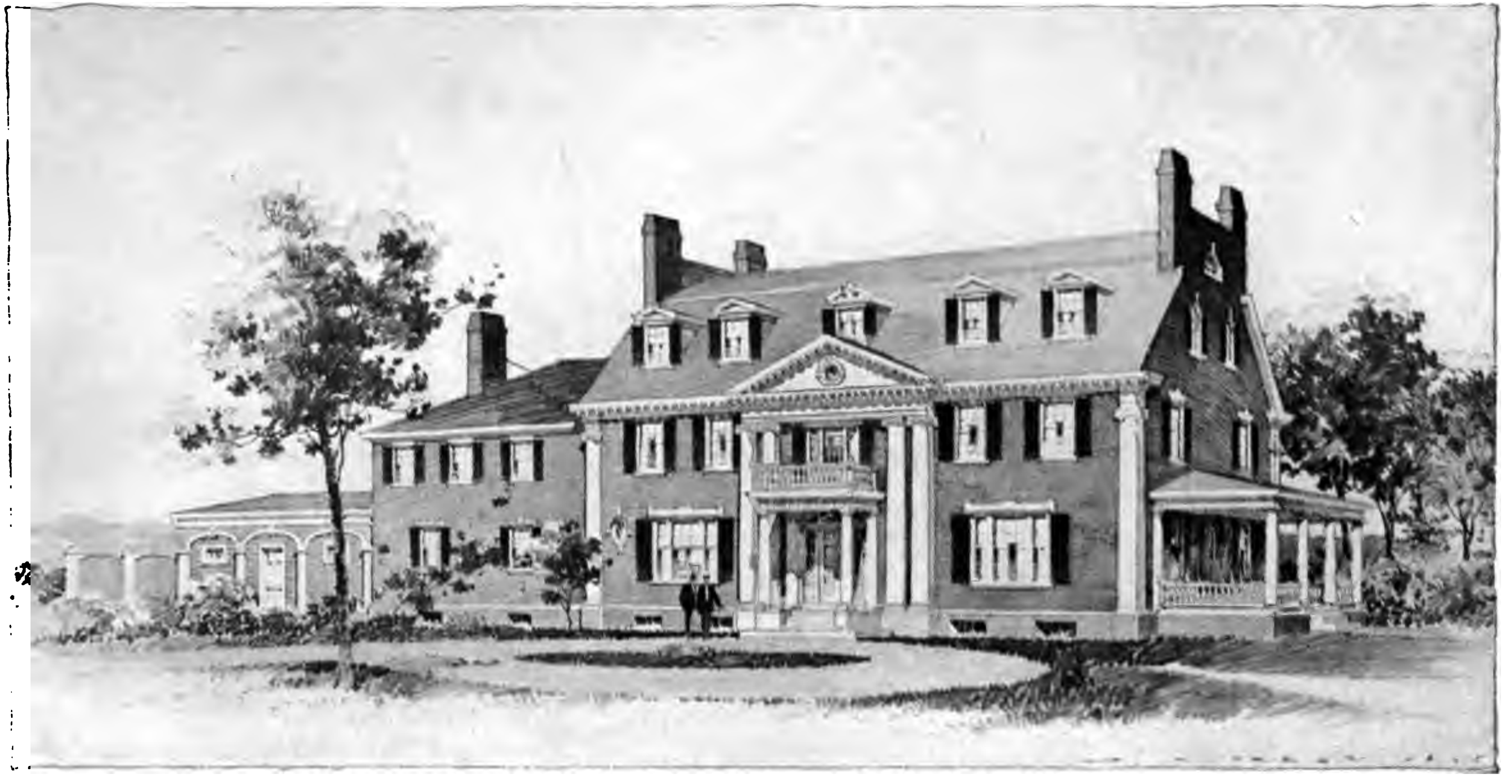

"EDENWOOD," THE RESIDENCE OF FRANCIS H. ADRIANCE, ESQ., NEW CANAAN, CONN.

Ernest M. A. Machado, Architect, Boston, Mass. Note the combination of Ionic and Doric Orders on the entrance feature, the effective use of Ionic Pilasters at the corners, and of the Doric Order on the side motif. For first-floor plan, see next succeeding plate.

Cyclopedia
of
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A General Reference Work on

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Authors and Collaborators

H. V. VON HOLST, A. B., S. B.

Architect, Chicago
Member, American Institute of Architects

◆

WALTER LORING WEBB, C. E.

Consulting Civil Engineer
Member, American Society of Civil Engineers
Author of "Railroad Construction," "Economics of Railroad Construction," etc.

◆

J. R. COOLIDGE, Jr., A. M.

Architect, Boston
Acting Director, Museum of Fine Arts, Boston

◆

HENRY J. BURT, B. S., C. E.

Structural Engineer for Holabird & Roche, Architects
Member, American Society of Civil Engineers
Member, Western Society of Civil Engineers
Member, Society for the Promotion of Engineering Education

◆

FRED T. HODGSON

Architect and Editor
Member, Ontario Association of Architects
Author of "Modern Carpentry," "Architectural Drawing, Self-Taught," "The Steel Square," "Modern Estimator," etc.

◆

FRANK O. DUFOUR, C. E.

Structural Engineer with Interstate Commerce Commission, Division of Valuation, Central District
Formerly Assistant Professor of Structural Engineering, University of Illinois
Member, American Society of Civil Engineers
Member, American Society for Testing Materials

◆

WM. H. LAWRENCE, S. B.

Professor of Architectural Engineering, Massachusetts Institute of Technology

Authors and Collaborators—Continued

EDWARD NICHOLS
Architect, Boston

◆

H. W. GARDNER, S. B.
Associate Professor of Architecture, Massachusetts Institute of Technology

◆

HERBERT E. EVERETT
Professor of the History of Art, University of Pennsylvania

◆

FRANK A. BOURNE, S. M.
Architect
Fellow, Boston Society of Architects
Associate, American Institute of Architects

◆

EDGAR S. BELDEN
Vice President, George A. Fuller Construction Company, Kansas City, Mo.

◆

GEORGE C. SHAAD, E. E.
Professor of Electrical Engineering, University of Kansas

◆

GLENN M. HOBBS, Ph. D.
Secretary and Educational Director, American School of Correspondence
Formerly Instructor, Department of Physics, University of Chicago
American Physical Society

◆

WM. G. SNOW, S. B.
Steam Heating Specialist
Author of "Furnace Heating," Joint Author of "Ventilation of Buildings
American Society of Mechanical Engineers

◆

ELIOT N. JONES, LL. B.
Of the Boston Bar

Authors and Collaborators—Continued

FRANK CHOUTEAU BROWN

Architect, Boston
Author of "Letters and Lettering"

* * *

EDWARD R. MAURER, B. C. E.

Professor of Mechanics, University of Wisconsin
Joint Author of "Principles of Reinforced Concrete Construction"

* * *

OTIS W. RICHARDSON, LL. B.

Of the Boston Bar

* * *

CHESTER L. POST, M. S.

Vice President of Condron Company, Structural Engineer, Chicago
Member of American Society of Civil Engineers

* * *

ALVAH HORTON SABIN, C. E.

Lecturer in New York University
Author of "Technology of Paint and Varnish," etc.
American Society of Mechanical Engineers

* * *

CHAS. B. BALL

Chief Sanitary Inspector, City of Chicago
American Society of Civil Engineers

* * *

SIDNEY T. STRICKLAND, S. B.

Massachusetts Institute of Technology
École des Beaux Arts, Paris

* * *

ERVIN KENISON, S. B.

Associate Professor of Mechanical Drawing, Massachusetts Institute of Technology

* * *

CHAS. L. HUBBARD, S. B., M. E.

Consulting Engineer on Heating, Ventilating, Lighting, and Power
Formerly with S. Homer Woodbridge Co.

Authors and Collaborators—Continued

W. HERBERT GIBSON, B. S., C. E.
Civil Engineer and Designer of Reinforced Concrete

◆

D. A. GREGG
Teacher in Pen and Pencil Rendering, Massachusetts Institute of Technology

◆

JAMES C. PLANT
Superintendent of Computing Division, Office of Supervising Architect, Washington, D.C.

◆

DANA PIERCE, B. A.
Electrical Engineer, Underwriters' Laboratories, Inc

◆

MORRIS WILLIAMS
Writer and Expert on Carpentry and Building

◆

WM. NEUBECKER
Instructor, Sheet Metal Department of New York Trade School

◆

WM. BEALL GRAY
Sanitary Engineer
Member, National Association of Master Plumbers

◆

GILBERT TOWNSEND, S. B.
With Ross & McFarlane, Montreal

◆

JESSIE M. SHEPHERD, A. B.
Head, Publication Department, American Technical Society

Authorities Consulted

THE editors have freely consulted the standard technical literature of America and Europe in the preparation of these volumes. They desire to express their indebtedness particularly to the following eminent authorities whose well-known works should be in the library of everyone connected with building.

Grateful acknowledgment is here made also for the invaluable cooperation of the foremost architects, engineers, and builders in making these volumes thoroughly representative of the very best and latest practice in the design and construction of buildings; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

J. B. JOHNSON, C. E.

Formerly Dean, College of Mechanics and Engineering, University of Wisconsin
Author of "Engineering Contracts and Specifications," "Materials of Construction," Joint Author of "Theory and Practice in the Designing of Modern Framed Structures"

❧

JOHN CASSAN WAIT, M. C. E., LL. B.

Counselor-at-Law and Consulting Engineer; Formerly Assistant Professor of Engineering at Harvard University
Author of "Engineering and Architectural Jurisprudence"

❧

T. M. CLARK

Fellow of the American Institute of Architects
Author of "Building Superintendence," "Architect, Builder, and Owner before the Law"

❧

FRANK E. KIDDER, C. E., Ph. D.

Consulting Architect and Structural Engineer; Fellow of the American Institute of Architects
Author of "Architects' and Builders' Pocket Book;" "Building Construction and Superintendence; Part I, Masons' Work; Part II, Carpenters' Work; Part III, Trussed Roofs and Roof Trusses;" "Churches and Chapels"

❧

N. CLIFFORD RICKER, D. Arch.

Professor of Architecture, University of Illinois
Author of "Simplified Formulas for Floors and Roofs"

❧

W. R. WARE

Formerly Professor of Architecture, Columbia University
Author of "Modern Perspective"

Authorities Consulted—Continued

CLARENCE A. MARTIN
Professor of Architecture at Cornell University
Author of "Details of Building Construction"

◆

FRANK N. SNYDER
Architect
Author of "Building Details"

◆

CHARLES H. SNOW
Author of "The Principal Species of Wood, Their Characteristic Properties"

◆

OWEN B. MAGINNIS
Author of "How to Frame a House, or House and Roof Framing"

◆

HALBERT P. GILLETTE, C. E.
Author of "Handbook of Cost Data for Contractors and Engineers"

◆

OLIVER COLEMAN
Author of "Successful Houses"

◆

CHAS. E. GREENE, A. M., C. E.
Formerly Professor of Civil Engineering, University of Michigan
Author of "Structural Mechanics"

◆

LOUIS de C. BERG
Author of "Safe Building"

◆

FRANK R. WALKER
Author of "The Building Estimator's Reference Book"

◆

IRA O. BAKER
Professor of Civil Engineering, University of Illinois
Author of "A Treatise on Masonry Construction"

◆

GEORGE P. MERRILL
Author of "Stones for Building and Decoration"

◆

FREDERICK W. TAYLOR, M. E., and SANFORD E. THOMPSON, S. B., C.E.
Joint Authors of "A Treatise on Concrete, Plain and Reinforced"

Authorities Consulted—Continued

A. W. BUEL and C. S. HILL

Joint Authors of "Reinforced Concrete"

❧

NEWTON HARRISON, E. E.

Author of "Electric Wiring, Diagrams and Switchboards"

❧

FREDERICK E. TURNEAURE, C. E., Dr. Eng.

Dean of the College of Engineering and Professor of Engineering, University of Wisconsin
Joint Author of "Public Water Supplies," "Theory and Practice of Modern Framed Structures," "Principles of Reinforced Concrete Construction"

❧

J. R. CRAVATH and V. R. LANSINGH

Joint Authors of "Practical Illumination"

❧

JOSEPH KENDALL FREITAG, B. S., C. E.

American Society of Civil Engineers
Author of "Architectural Engineering," "Fireproofing of Steel Buildings," "Fire Prevention and Fire Protection"

❧

WILLIAM H. BIRKMIRE, C. E.

Author of "Planning and Construction of High Office Buildings," "Architectural Iron and Steel, and Its Application in the Construction of Buildings," "Compound Riveted Girders," "Skeleton Structures," etc.

❧

EVERETT U. CROSBY and HENRY A. FISKE

Joint Authors of "Handbook of Fire Protection for Improved Risk"

❧

CARNEGIE STEEL COMPANY

Authors of "Pocket Companion, Containing Useful Information and Tables Appertaining to the Use of Steel"

❧

ALPHA PIERCE JAMISON, M. E.

Assistant Professor of Mechanical Drawing, Purdue University
Author of "Advanced Mechanical Drawing"

❧

H. G. RITCHEY

Superintendent of Construction, U. S. Public Buildings
Author of "A Handbook for Superintendents of Construction, Architects, Builders, and Building Inspectors"

Authorities Consulted—Continued

HENRY McGOODWIN

Author of "Architectural Shades and Shadows"

❧

VIGNOLA

Author of "The Five Orders of Architecture," American Edition by Prof. Ware

❧

CHAS. D. MAGINNIS

Author of "Pen Drawing, An Illustrated Treatise"

❧

FRANZ S. MEYER

Professor in the School of Industrial Art, Karlsruhe
Author of "Handbook of Ornament," American Edition

❧

RUSSELL STURGIS

Author of "A Dictionary of Architecture and Building," and "How to Judge Architecture"

❧

A. D. F. HAMLIN, A. M.

Professor of Architecture at Columbia University
Author of "A Textbook of the History of Architecture"

❧

RALPH ADAMS CRAM, Litt. D.

Professor of Architecture, Massachusetts Institute of Technology
Author of "Church Building"

❧

C. H MOORE

Author of "Development and Character of Gothic Architecture"

❧

ROLLA C. CARPENTER, C. E., M. M. E.

Professor of Experimental Engineering, Cornell University
Author of "Heating and Ventilating Buildings"

❧

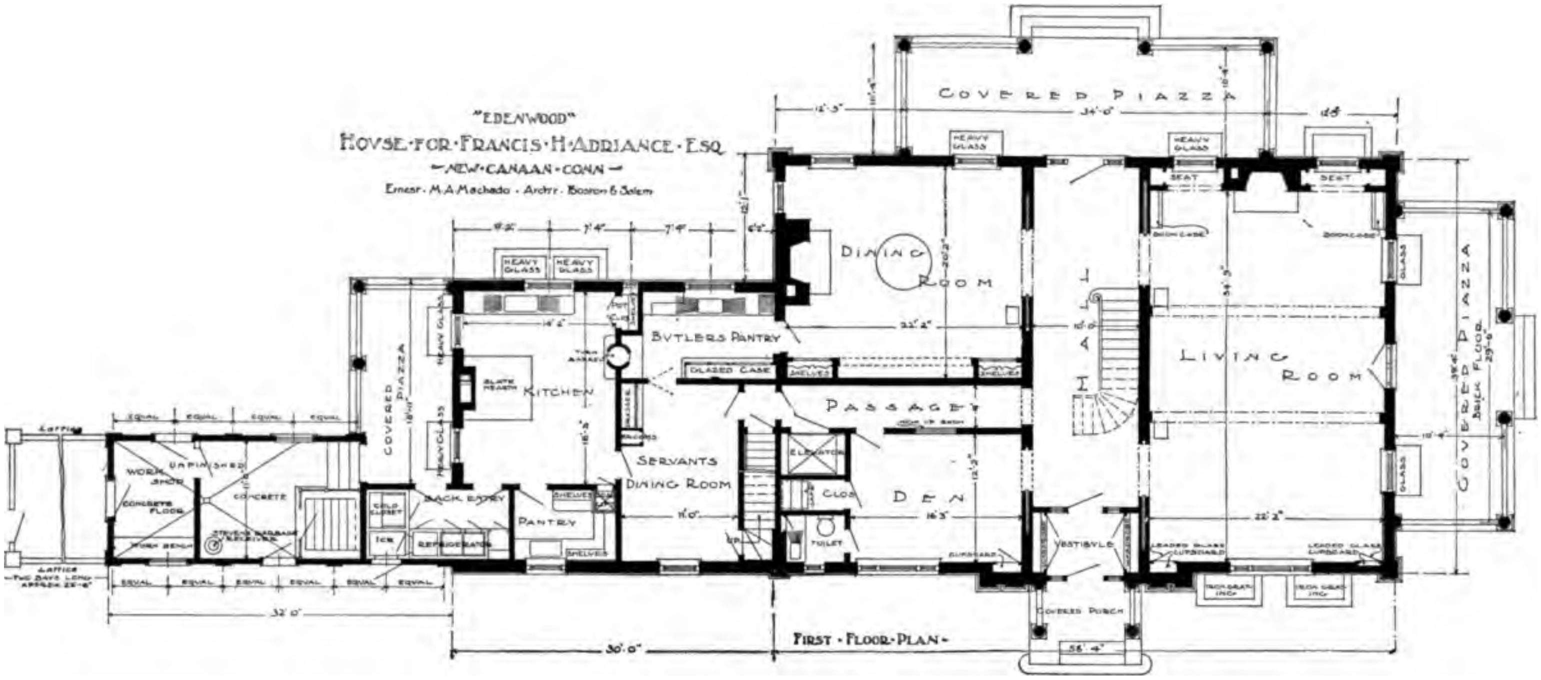
WILLIAM PAUL GERHARD

Author of "A Guide to Sanitary House Inspection," "Sanitation of Public Buildings," "Theater Fires and Panics," and "Water Supply, Sewerage and Plumbing of Modern City Buildings"

❧

I. J. COSGROVE

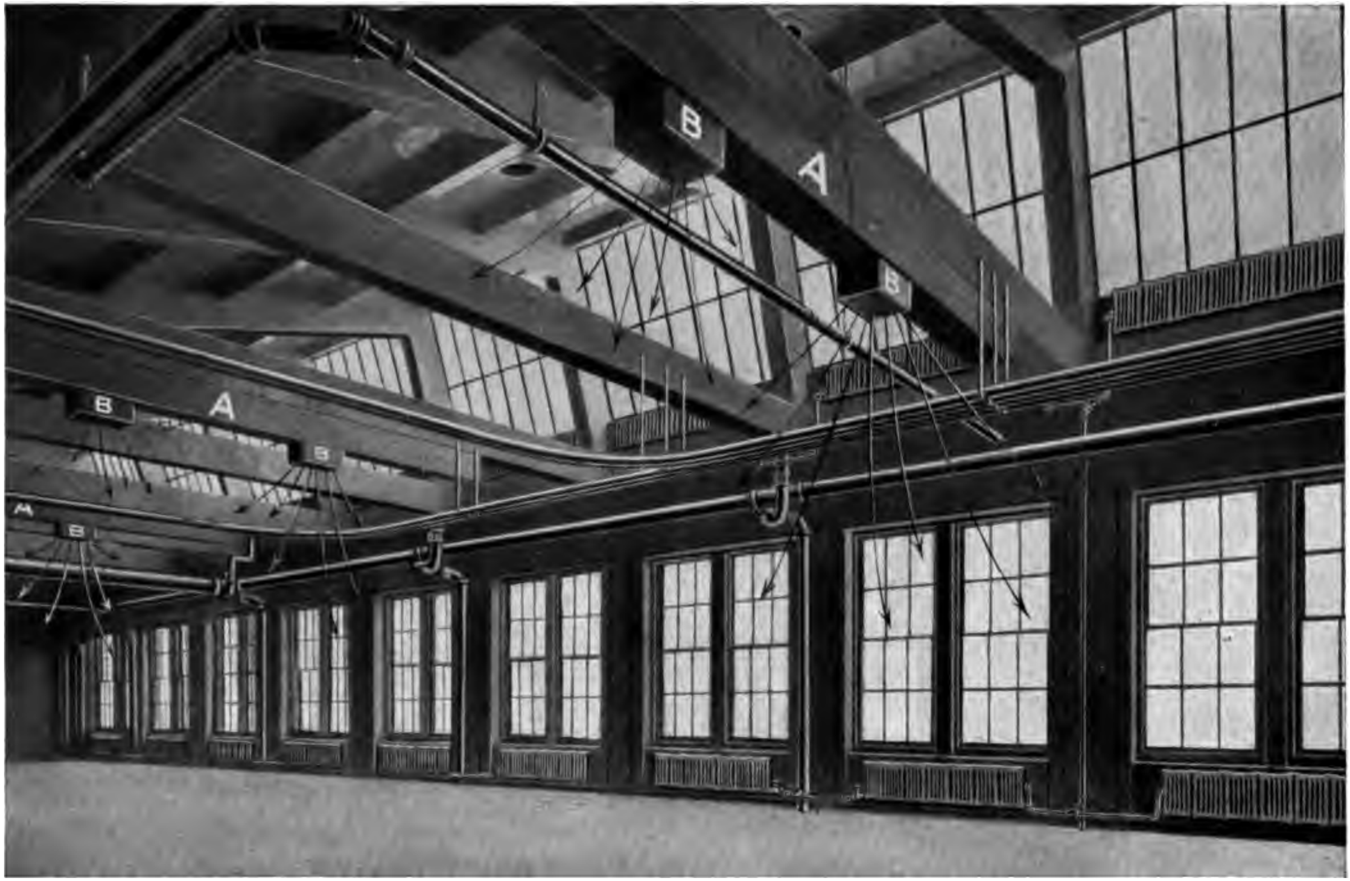
Author of "Principles and Practice of Plumbing"



FIRST-FLOOR PLAN OF "EDENWOOD," RESIDENCE OF FRANCIS H. ADRIANCE, ESQ., NEW CANAAN, CONN.

Ernest M. A. Machado, Architect, Boston, Mass.

For Exterior View, Reproduced in Color, See Frontispiece in this Volume.



HEATING AND VENTILATING INSTALLATION IN PRESSROOM OF CURTIS PUBLISHING COMPANY, PHILADELPHIA PENNSYLVANIA

View Shows Generator Air Ducts *A*, and Delivery of Warm Air *B*, from Vento Heaters. The Use of Wall Radiators Provides Heating Surface without Interfering with the Light from the Side and Mansard Windows

Courtesy of American Radiator Company, Chicago

Foreword

THE rapid evolution of constructive methods in recent years, as illustrated in the use of steel and concrete, and the increased size and complexity of buildings, has created the necessity for an authority which shall embody accumulated experience and approved practice along a variety of correlated lines. The Cyclopedia of Architecture, Carpentry, and Building is designed to fill this acknowledged need.

¶ There is no industry that compares with Building in the close interdependence of its subsidiary trades. The Architect, for example, who knows nothing of Steel or Concrete construction is today as much out of place on important work as the Contractor who cannot make intelligent estimates, or who understands nothing of his legal rights and responsibilities. A carpenter must now know something of Masonry, Electric Wiring, and, in fact, all other trades employed in the erection of a building; and the same is true of all the craftsmen whose handiwork will enter into the completed structure.

¶ Neither pains nor expense have been spared to make the present work the most comprehensive and authoritative on the subject of Building and its allied industries. The aim has been, not merely to create a work which will appeal to the trained expert, but one that will commend itself also to the beginner and the self-taught, practical man by giving him a working knowledge of the principles and methods, not only of his own particular trade, but of all other branches of the Building Industry as well. The various sections have been prepared especially for home study, each written by an acknowledged authority on the subject. The arrangement of matter is such as to carry the student forward by easy stages. Series of review questions are inserted in each volume, enabling the reader to test his knowledge and make it a permanent possession. The illustrations have been selected with unusual care to elucidate the text.

❡ The work will be found to cover many important topics on which little information has heretofore been available. This is especially apparent in such sections as those on Steel Construction; Reinforced Concrete Construction; Building Superintendence; Estimating; Contracts and Specifications, including the principles and methods of awarding and executing Government contracts; and Building Law.

❡ In conclusion, grateful acknowledgment is due the staff of authors and collaborators, without whose hearty co-operation this work would have been impossible.

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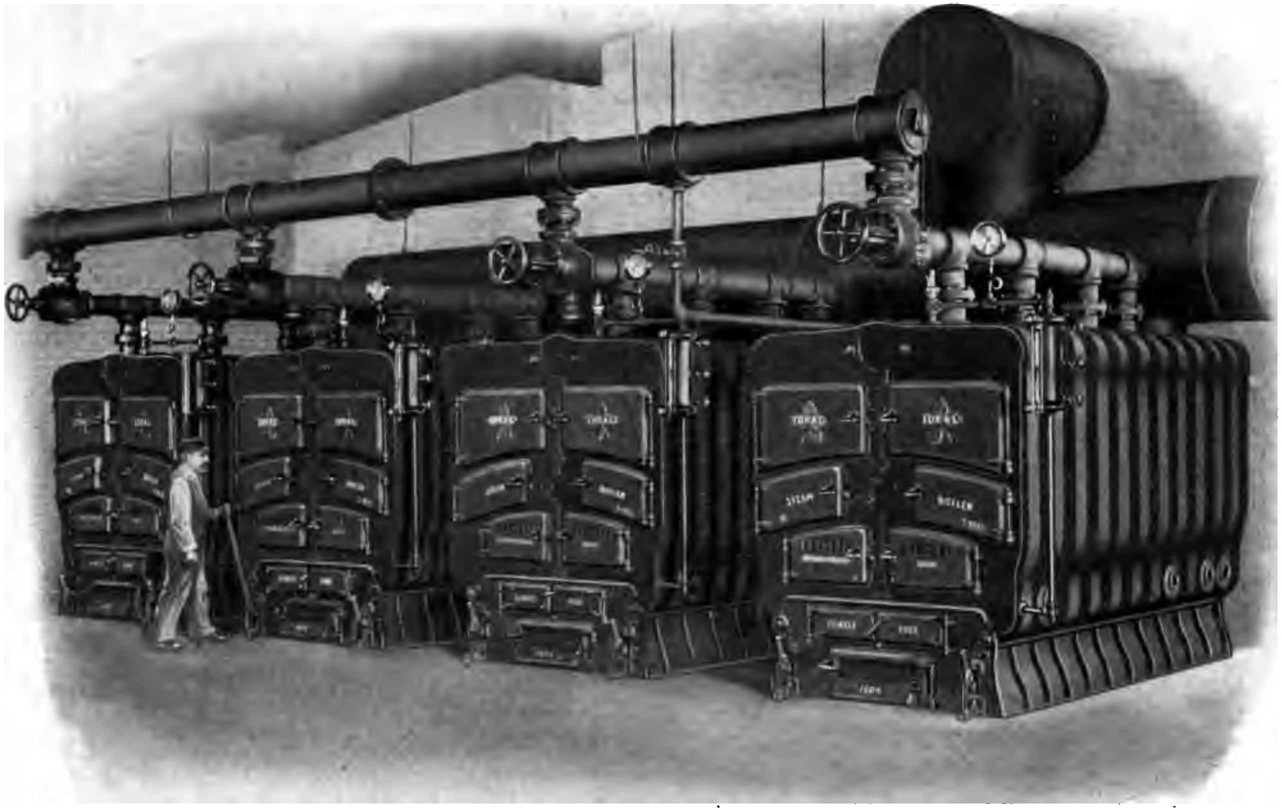
† For professional standing of authors, see list of Authors and Collaborators at front of volume.



INSTALLATION OF IDEAL 48-INCH SECTIONAL STEAM BOILERS
Courtesy of American Radiator Company, Chicago

HEATING AND VENTILATION

PART I

SYSTEMS OF WARMING

Any system of warming must include, *first,* the combustion of fuel, which may take place in a fireplace, stove, or furnace, or a steam, or hot-water boiler; *second,* a system of transmission, by means of which the heat may be carried, with as little loss as possible, to the place where it is to be used for warming; and *third,* a system of diffusion, which will convey the heat to the air in a room, and to its walls, floors, etc., in the most economical way.

Stoves. The simplest and cheapest form of heating is the stove. The heat is diffused by radiation and convection directly to the objects and air in the room, and no special system of transmission is required. The stove is used largely in the country, and is especially adapted to the warming of small dwelling-houses and isolated rooms.

Furnaces. Next in cost of installation and in simplicity of operation, is the hot-air furnace. In this method, the air is drawn over heated surfaces and then transmitted through pipes, while at a high temperature, to the rooms where heat is required. Furnaces are used largely for warming dwelling-houses, also churches, halls, and schoolhouses of small size. They are more costly than stoves, but have certain advantages over that form of heating. They require less care, as several rooms may be warmed from a single furnace; and, being placed in the basement, more space is available in the rooms above, and the dirt and litter connected with the care of a stove are largely done away with. They require less care, as only one fire is necessary to warm all the rooms in a house of ordinary size. One great advantage in the furnace method of warming comes from the constant supply of fresh air which is required to bring the heat into the rooms. While this is greatly to be desired from a sanitary standpoint, it calls for the consumption of a larger amount of fuel than would otherwise be necessary. This is true because heat is required to warm the fresh air from out of doors up to the temperature of the rooms, in addition to replacing the heat lost by leakage and conduction through walls and windows.

A more even temperature may be maintained with a furnace than by the use of stoves, owing to the greater depth and size of the fire, which allows it to be more easily controlled.

When a building is placed in an exposed location, there is often difficulty in warming rooms on the north and west sides, or on that side toward the prevailing winds. This may be overcome to some extent by a proper location of the furnace and by the use of extra large pipes for conveying the hot air to those rooms requiring special attention.

Direct Steam. Direct steam, so called, is widely used in all classes of buildings, both by itself and in combination with other systems. The first cost of installation is greater than for a furnace; but the amount of fuel required is less, as no outside air supply is necessary. If used for warming hospitals, schoolhouses, or other buildings where a generous supply of fresh air is desired, this method must be supplemented by some form of ventilating system.

One of the principal advantages of direct steam is the ability to heat all rooms alike, regardless of their location or of the action of winds.

When compared with hot-water heating, it has still another desirable feature—which is its freedom from damage by the freezing of water in the radiators when closed, which is likely to happen in unused rooms during very cold weather in the case of the former system.

On the other hand, the sizes of the radiators must be proportioned for warming the rooms in the coldest weather, and unfortunately there is no satisfactory method of regulating the amount of heat in mild weather, except by shutting off or turning on steam in the radiators at more or less frequent intervals as may be required, unless one of the expensive systems of automatic control is employed. In large rooms, a certain amount of regulation can be secured by dividing the radiation into two or more parts, so that different combinations may be used under varying conditions of outside temperature. If two radiators are used, their surface should be proportioned, when convenient, in the ratio of 1 to 2, in which case one-third, two-thirds, or the whole power of the radiation can be used as desired.

Indirect Steam. This system of heating combines some of the advantages of both the furnace and direct steam, but is more costly to install than either of these. The amount of fuel required is about the same as for furnace heating, because in each case the cool fresh air must be warmed up to the temperature of the room, before it can become a medium for conveying heat to offset that lost by leakage and conduction through walls and windows.

A system for indirect steam may be so designed that it will supply a greater quantity of fresh air than the ordinary form of furnace, in which case the cost of fuel will of course be increased in proportion to the volume of air supplied. Instead of placing the radiators in the rooms, a special form of heater is supported near the basement ceiling and encased in either galvanized iron or brick. A cold-air supply duct is connected with the space below the heater, and warm air pipes are taken from the top and connected with registers in the rooms to be heated the same as in the case of furnace heating.

A separate stack or heater may be provided for each register if the rooms are large; but, if small and so located that they may be reached by short runs of horizontal pipe, a single heater may serve for two or more rooms.

The advantage of indirect steam over furnace heating comes from the fact that the stacks may be placed at or near the bases of the flues leading to the different rooms, thus doing away with long, horizontal runs of pipe, and counteracting to a considerable extent the effect of wind pressure upon exposed rooms. Indirect and direct heating are often combined to advantage by using the former for the more important rooms, where ventilation is desired, and the latter for rooms more remote or where heat only is required.

Another advantage is the large ratio between the radiating surface and grate-area, as compared with a furnace; this results in a large volume of air being warmed to a moderate temperature instead of a smaller quantity being heated to a much higher temperature, thus giving a more agreeable quality to the air and rendering it less dry.

Indirect steam is adapted to all the buildings mentioned in connection with furnace heating, and may be used to much better advantage in those of large size. This applies especially to cases where more than one furnace is necessary; for, with steam heat, a single boiler, or a battery of boilers, may be made to supply heat for a building of any size, or for a group of several buildings, if desired, and is much easier to care for than several furnaces widely scattered.

Direct-Indirect Radiators. These radiators are placed in the room the same as the ordinary direct type. The construction is such that when the sections are in place, small flues are formed between them; and air, being admitted through an opening in the outside wall, passes upward through them and becomes heated before entering the room. A switch damper is placed in the casing at the base of the radiator, so that air may be taken from the room itself instead of from out of doors, if so desired. Radiators of this kind are not used to any great extent, as there is likely to be more or less leakage of cold air into the room around the base. If ventilation is required, it is better to use the regular form of indirect heater with flue and register, if possible. It is sometimes desirable to partially ventilate an isolated room where it would be impossible to run a flue, and in cases of this kind the direct-indirect form is often useful.

Direct Hot Water. Hot water is especially adapted to the warming of dwellings and greenhouses, owing to the ease with which the temperature can be regulated. When steam is used, the radiators are always at practically the same temperature, while with hot water the temperature can be varied at will. A system for hot-water heating costs more to install than one for steam, as the radiators must be larger and the pipes more carefully run. On the other hand, the cost of operating is somewhat less, because the water need be carried only at a temperature sufficiently high to warm the rooms properly in mild weather, while with steam the building is likely to become overheated, and more or less heat wasted through open doors and windows.

A comparison of the relative costs of installing and operating hot-air, steam, and hot-water systems, is given in Table I.

TABLE I

Relative Cost of Heating Systems

	HOT AIR	STEAM	HOT WATER
Relative cost of apparatus	9	13	15
Relative cost, adding repairs and fuel for five years	29½	29¾	27
Relative cost, adding repairs and fuel for fifteen years	81	63	52½

One disadvantage in the use of hot water is the danger from freezing when radiators are shut off in unused rooms. This makes it necessary in very cold weather to have all parts of the system turned on sufficiently to produce a circulation, even if very slow. This is sometimes accomplished by drilling a very small hole (about $\frac{1}{8}$ inch) in the valve-seat, to that when closed there will still be a very slow circulation through the radiator, thus preventing the temperature of the water from reaching the freezing point.

Indirect Hot Water. This is used under the same conditions as indirect steam, but more especially in the case of dwellings and hospitals. When applied to other and larger buildings, it is customary to force the water through the mains by means of a pump. Larger heating stacks and supply pipes are required than for steam; but the arrangement and size of air-flues and registers are practically the same, although they are sometimes made slightly larger in special cases.

Exhaust Steam. Exhaust steam is used for heating in connection with power plants, as in shops and factories, or in office buildings which have their own lighting plants. There are two methods of using exhaust steam for heating purposes. One is to carry a back pressure of 2 to 5 pounds on the engines, depending upon the length and size of the pipe mains; and the other is to use some form of *vacuum system* attached to the returns or air-valves, which tends to reduce the back pressure rather than to increase it.

Where the first method is used and a back pressure carried, either the boiler pressure or the cut-off of the engines must be increased, to keep the mean effective pressure the same and not reduce the horsepower delivered. In general it is more economical to utilize the exhaust steam for heating. There are instances, however, where the relation between the quantities of steam required for heating and for power are such—especially if the engines are run condensing—that it is better to throw the exhaust away and heat with live steam. Where the vacuum method is used, these difficulties are avoided; and for this reason that method is coming into quite common use. If the condensation from the exhaust steam is returned to the boilers, the oil must first be removed; this is usually accomplished by passing the steam through some form of grease extractor as it leaves the engine. The water of condensation is often passed through a separating tank in addition to this, before it is delivered to the return pumps. It is better, however, to remove a portion of the oil before the steam enters the heating system; otherwise a coating will be formed upon the inner surfaces of the radiators, which will reduce their efficiency to some extent.

Forced Blast. This method of heating, in different forms, is used for the warming of factories, schools, churches, theaters, halls—in fact, any large building where good ventilation is desired. The air for warming is drawn or forced through a heater of special design, and discharged by a fan or blower into ducts which lead to registers placed in the rooms to be warmed. The heater is usually made up in sections, so that steam may be admitted to or shut off from any section independently of the others, and the temperature of the air regulated in this manner. Sometimes a *by-pass damper* is attached, so that part of the air will pass through the heater and part around or over it; in this way the proportions of cold and heated air may be so adjusted as to give the desired temperature to the air entering the rooms. These forms of regulation are common where a blower is used for warming a single room, as in the case of a church or hall; but where several rooms are warmed, as in a schoolhouse. it is customary to use the main or primary heater at the blower for warming the air to a given temperature (somewhat below that which is actually required), and to supplement this by placing secondary coils or heaters at the bottoms of the flues leading to the different rooms. By means of this arrangement, the temperature of each room can be regulated independently of the others. The so-called *double-duct* system is sometimes employed. In this case, two ducts are carried to each register, one supplying hot air and the other cold or tempered air; and a damper for mixing these in the right proportions is placed in the flue, below the register.

Electric Heating. Unless electricity can be produced at a very low cost, it is not practicable for heating residences or large buildings. The electric heater, however, has quite a wide field of application in heating small offices, bathrooms, electric cars, etc. It is a convenient method of warming isolated rooms on cold mornings, in late spring and early fall, when the regular heating apparatus of the building is not in operation. It has the advantage of being instantly available, and the amount of heat can be regulated at will. Electric heaters are clean, do not vitiate the air, and are easily moved from place to place.

PRINCIPLES OF VENTILATION

Closely connected with the subject of heating is the problem of maintaining air of a certain standard of purity in the various buildings occupied.

The introduction of pure air can be done properly only in connection with some system of heating; and no system of heating is complete without a supply of pure air, depending in amount upon the kind of building and the purpose for which it is used.

Composition of the Atmosphere. Atmospheric air is not a simple substance but a mechanical mixture. Oxygen and nitrogen, the principal constituents, are present in very nearly the proportion of one part of oxygen to four parts of nitrogen by weight. Carbonic acid gas, the product of all combustion, exists in the proportion of 3 to 5 parts in 10,000 in the open country. Water in the form of vapor, varies greatly with the temperature and with the exposure of the air to open bodies of water. In addition to the above, there are generally present, in variable but exceedingly small quantities, ammonia, sulphuretted hydrogen, sulphuric, sulphurous, nitric, and nitrous acids, floating organic and inorganic matter, and local impurities. Air also contains ozone, which is a peculiarly active form of oxygen; and lately another constituent called *argon* has been discovered.

Oxygen is the most important element of the air, so far as both heating and ventilation are concerned. It is the active element in the chemical process of combustion and also in the somewhat similar process which takes place in the respiration of human beings. Taken into the lungs, it acts upon the excess of carbon in the blood, and possibly upon other ingredients, forming chemical compounds which are thrown off in the act of respiration or breathing.

Nitrogen. The principal bulk of the atmosphere is nitrogen, which exists uniformly diffused with oxygen and carbonic acid gas. This element is practically inert in all processes of combustion or respiration. It is not affected in composition, either by passing through a furnace during combustion or through the lungs in the process of respiration. Its action is to render the oxygen less active, and to absorb some part of the heat produced by the process of oxidation.

Carbonic acid gas is of itself only a neutral constituent of the atmosphere, like nitrogen; and—contrary to the general impression—its presence in moderately large quantities (if uncombined with other substances) is neither disagreeable nor especially harmful. Its presence, however, in air provided for respiration, decreases the readiness with which the carbon of the blood unites with the oxygen of the air; and therefore, when present in sufficient quantity, it may cause indirectly, not only serious, but fatal results. The real harm of a vitiated atmosphere, however, is caused by the other constituent gases and by the minute organisms which are produced in the process of respiration. It is known that these other impurities exist in fixed proportion to the amount of carbonic acid present in an atmosphere vitiated by respiration. Therefore, as the relative proportion of carbonic acid can easily be determined by experiment, the fixing of a standard limit of the amount in which it may be allowed, also limits the amounts of other impurities which are found in combination with it.

When carbonic acid is present in excess of 10 parts in 10,000 parts of air, a feeling of weariness and stuffiness, generally accompanied by a headache, will be experienced; while with even 8 parts in 10,000 parts a room would be considered close. For general considerations of ventilation, the limit should be placed at 6 to 7 parts in 10,000, thus allowing an increase of 2 to 3 parts over that present in outdoor air, which may be considered to contain four parts in 10,000 under ordinary conditions.

Analysis of Air. An accurate qualitative and quantitative analysis of air samples can be made only by an experienced chemist. There are, however, several approximate methods for determining the amount of carbonic acid present, which are sufficiently exact for practical purposes. Among these the following is one of the simplest:

The necessary apparatus consists of six clean, dry, and tightly corked bottles, containing respectively 100, 200, 250, 300, 350, and 400 cubic centimeters, a glass tube containing exactly 15 cubic centimeters to a given mark, and a bottle of perfectly clear, fresh limewater. The bottles should be filled with the air to be examined by means of a hand-ball syringe. Add to the smallest bottle 15 cubic centimeters of the limewater, put in the cork, and shake well. If the limewater has a milky appearance, the amount of carbonic acid will be at least 16 parts in 10,000. If the contents of the bottle remain clear, treat the bottle of 200 cubic centimeters in the same manner; a milky appearance or turbidity in this would indicate 12 parts in 10,000. In a similar manner, turbidity in the 250 cubic centimeter bottle indicates

10 parts in 10,000; in the 300, 8 parts; in the 350, 7 parts; and in the 400, less than 6 parts. The ability to conduct more accurate analyses can be attained only by special study and a knowledge of chemical properties and of methods of investigation.

Another method similar to the above, makes use of a glass cylinder containing a given quantity of limewater and provided with a piston. A sample of the air to be tested is drawn into the cylinder by an upward movement of the piston. The cylinder is then thoroughly shaken, and if the limewater shows a milky appearance, it indicates a certain proportion of carbonic acid in the air. If the limewater remains clear, the air is forced out, and another cylinder full drawn in, the operation being repeated until the limewater becomes milky. The size of the cylinder and the quantity of limewater are so proportioned that a change in color at the first, second, third, etc., cylinder full of air indicates different proportions of carbonic acid. This test is really the same in principle as the one previously described; but the apparatus used is in more convenient form.

Air Required for Ventilation. The amount of air required to maintain any given standard of purity can very easily be determined, provided we know the amount of carbonic acid given off in the process of respiration. It has been found by experiment that the average production of carbonic acid by an adult at rest is about .6 cubic foot per hour. If we assume the proportion of this gas as 4 parts in 10,000 in the external air, and are to allow 6 parts in 10,000 in an occupied room, the gain will be 2 parts in 10,000; or, in other words, there will be $\frac{2}{10{,}000} = .0002$ cubic foot of carbonic acid mixed with each cubic foot of fresh air entering the room. Therefore, if one person gives off .6 cubic foot of carbonic acid per hour, it will require $.6 \div .0002 = 3{,}000$ cubic feet of air per hour per person to keep the air in the room at the standard of purity assumed—that is, 6 parts of carbonic acid in 10,000 of air.

Table II has been computed in this manner, and shows the amount of air which must be introduced for each person in order to maintain various standards of purity.

While this table gives the theoretical quantities of air required for different standards of purity, and may be used as a guide, it will be better in actual practice to use quantities which experience has shown to give good results in different types of buildings. In auditoriums where the cubic space per individual is large, and in which the atmosphere is thoroughly fresh before the rooms are occupied, and the occupancy is of only two or three hours' duration, the air-supply may be reduced somewhat from the figures given below.

TABLE II

Quantity of Air Required per Person

Standard Parts of Carbonic Acid in 10,000 of Air in Room	Cubic Feet of Air Required per Person	
	Per Minute	Per Hour
5	100	6,000
6	50	3,000
7	33	2,000
8	25	1,500
9	20	1,200
10	16	1,000

Table III represents good modern practice and may be used with satisfactory results:

TABLE III

Air Required for Ventilation of Various Classes of Buildings

Air-Supply per Occupant for	Cubic Feet per Minute	Cubic Feet per Hour
Hospitals	80 to 100	4, 800 to 6, 000
High Schools	50	3, 000
Grammar Schools	40	2, 400
Theaters and Assembly Halls	25	1, 500
Churches	20	1, 200

When possible, the air-supply to any given room should be based upon the number of occupants. It sometimes happens, however, that this information is not available, or the character of the room is such that the number of persons occupying it may vary, as in the case of public waiting rooms, toilet rooms, etc. In instances of this kind, the required air-volume may be based upon the number of changes per hour. In using this method, various considerations must be taken into account, such as the use of the room and its condition as to crowding, character of occupants, etc. In general, the following will be found satisfactory for average conditions:

TABLE IV

Number of Changes of Air Required in Various Rooms

Use of Room	Changes of Air per Hour
Public Waiting Room	4 to 5
Public Toilets	5 " 6
Coat and Locker Rooms	4 " 5
Museums	3 " 4
Offices, Public	4 " 5
Offices, Private	3 " 4
Public Dining Rooms	4 " 5
Living Rooms	3 " 4
Libraries, Public	4 " 5
Libraries, Private	3 " 4

Force for Moving Air. Air is moved for ventilating purposes in two ways: (1) by expansion due to heating; (2) by mechanical means. The effect of heat on the air is to increase its volume and therefore lessen its density or weight, so that it tends to rise and is replaced by the colder air below. The available force for moving air obtained in this way is very small, and is quite likely to be overcome by wind or external causes. It will be found in general that the heat used for producing velocity in this manner, when transformed into work in the steam engine, is greatly in excess of that required to produce the same effect by the use of a fan.

Ventilation by mechanical means is performed either by pressure or by suction. The former is used for delivering fresh air into a building, and the latter for removing the foul air from it. By both processes the air is moved without change in temperature, and the force for moving must be sufficient to overcome the effects of wind or changes in outside temperature. Some form of fan is used for this purpose.

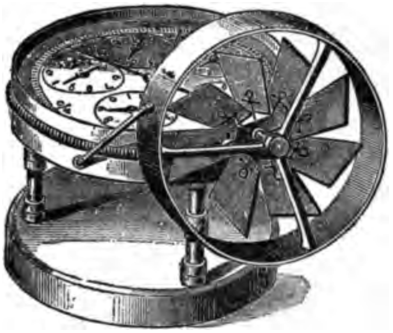


Fig. 1. Common Form of Anemometer, for Measuring Velocity of Air-Currents.

Measurements of Velocity. The velocity of air in ventilating ducts and flues is measured directly by an instrument called an anemometer. A common form of this instrument is shown in Fig. 1. It consists of a series of flat vanes attached to an axis, and a series of dials.

The revolution of the axis causes motion of the hands in proportion to the velocity of the air, and the result can be read directly from the dials for any given period.

For approximate results the anemometer may be slowly moved across the opening in either vertical or horizontal parallel lines, so that the readings will be made up of velocities taken from all parts of the opening. For more accurate work, the opening should be divided into a number of squares by means of small twine, and readings taken at the center of each. The mean of these readings will give the average velocity of the air through the entire opening.

AIR DISTRIBUTION

The location of the air inlet to a room depends upon the size of the room and the purpose for which it is used. In the case of living rooms in dwelling-houses, the registers are placed either in the floor or in the wall near the floor; this brings the warm air in at the coldest part of the room and gives an opportunity for warming or drying the feet if desired. In the case of schoolrooms, where large volumes of warm air at moderate temperatures are required, it is best to discharge it through openings in the wall at a height of 7 or 8 feet from the floor; this gives a more even distribution, as the warmer air tends to rise and hence spreads uniformly under the ceiling; it then gradually displaces other air, and the room becomes filled with pure air without sensible currents or drafts. The cooler air sinks to the bottom of the room, and can be taken off through ventilating registers placed near the floor. The relative positions of the inlet and outlet are often governed to some extent by the building construction; but, if possible, they should both be located in the same side of the room. Figs. 2, 3, and 4 show common arrangements.

The vent outlet should always, if possible, be placed in an inside wall; otherwise it will become chilled and the air-flow through it will become sluggish. In theaters and churches which are closely packed, the air should enter at or near the floor, in finely-divided streams; and the discharge ventilation should be through openings in the ceiling. The reason for this is the large amount of animal heat given off from the bodies of the audience; this causes the air to become still further heated after entering the room, and the tendency is to rise continuously from floor to ceiling, thus carrying away all impurities from respiration as fast as they are given off.

All audience halls in which the occupants are closely seated should be treated in the same manner, when possible. This, however, cannot always be done, as the seats are often made removable so that the floor can be used for other purposes. In cases of this kind, part of the air may be introduced through floor registers placed along the outer aisles, and the remainder by means of wall inlets the same as for schoolrooms. The discharge ventilation should be partly through registers near the floor, supplemented by ample ceiling vents for use when the hall is crowded or the outside temperature high.

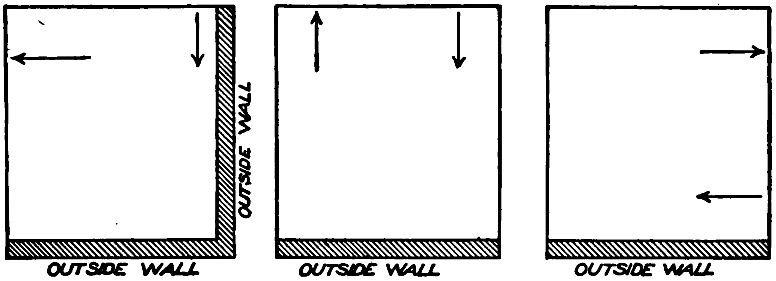


Fig. 2. Fig. 3. Fig. 4.

Diagrams Showing Relative Positions of Air Inlets and Outlets as Commonly Arranged.

The matter of air-velocities, size of flues, etc., will be taken up under the head of "Indirect Heating."

HEAT LOSS FROM BUILDINGS

A *British Thermal Unit*, or B. T. U., has been defined as the amount of heat required to raise the temperature of one pound of water one degree F. This measure of heat enters into many of the calculations involved in the solving of problems in heating and ventilation, and one should familiarize himself with the exact meaning of the term.

Causes of Heat Loss. The heat loss from a building is due to the following causes: (1) radiation and conduction of heat through walls and windows; (2) leakage of warm air around doors and windows and through the walls themselves; and (3) heat required to warm the air for ventilation.

Loss through Walls and Windows. The loss of heat through the walls of a building depends upon the material used in construction

TABLE V

Heat Losses in B. T. U. per Square Foot of Surface per Hour—Southern Exposure

MATERIAL	DIFFERENCE BETWEEN INSIDE AND OUTSIDE TEMPERATURES									
	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
8-in. Brick Wall	5	9	13	18	22	27	31	36	40	45
12-in. Brick Wall	4	7	10	13	16	20	23	26	30	33
16-in. Brick Wall	3	5	8	10	13	16	19	22	24	27
20-in. Brick Wall	2.8	4.5	7	9	11	14	16	18	20	23
24-in. Brick Wall	2.5	4	6	8	10	12	14	16	18	20
28-in. Brick Wall	2	3.5	5	7	9	11	13	14	16	18
32-in. Brick Wall	1.5	3	4.5	6	8	10	11	13	15	16
Single Window	12	24	36	49	60	73	85	93	110	122
Double Window	8	16	24	32	40	48	56	62	70	78
Single Skylight	11	21	31	42	52	63	73	84	94	104
Double Skylight	7	14	20	28	35	42	48	56	62	70
1-in. Wooden Door	4	8	12	16	20	24	28	32	36	40
2-in. Wooden Door	3	5	8	11	14	17	20	23	25	28
2-in. Solid Plaster Partition	6	12	18	24	30	36	42	48	54	60
3-in. Solid Plaster Partition	5	10	15	20	25	30	35	40	45	50
Concrete Floor on Brick Arch	2	4	6.5	9	11	13	15	18	20	22
Wood Floor on Brick Arch	1.5	3	4.5	6	7	9	10	12	13	15
Double Wood Floor	1	2	3	4	5	6	7	8	9	10
Walls of Ordinary Wooden Dwellings	3	5	8	10	13	16	19	22	24	27

For *solid stone walls*, multiply the figures for brick of the same thickness by 1.7. Where rooms have a *cold attic above or cellar beneath*, multiply the heat loss through walls and windows by 1.1.

Correction for Leakage. The figures given in the above table apply only to the most thorough construction. For the average well-built house, the results should be increased about 10 per cent; for fairly good construction, 20 per cent; and for poor construction, 30 per cent.

Table V applies only to a southern exposure; for other exposures multiply the heat loss given in Table V by the factors given in Table VI.

of the wall, the thickness, the number of layers, and the difference between the inside and outside temperatures. The exact amount of heat lost in this way is very difficult to determine theoretically, hence we depend principally on the results of experiments.

Loss by Air-Leakage. The leakage of air from a room varies from one to two or more changes of the entire contents per hour, depending upon the construction, opening of doors, etc. It is common practice to allow for one change per hour in well-constructed buildings where two walls of the room have an outside exposure. As the amount of leakage depends upon the extent of exposed wall and window surface, the simplest way of providing for this is to increase

TABLE VI
Factors for Calculating Heat Loss for Other than Southern Exposures

Exposure	Factor
N.	1.32
E.	1.12
S.	1.0
W.	1.20
N. E.	1.22
N. W.	1.26
S. E.	1.06
S. W.	1.10
N., E., S., and W., or total exposure	1.16

the total loss through walls and windows by a factor depending upon the tightness of the building construction. Authorities differ considerably in the factors given for heat losses, and there are various methods for computing the same. The figures given in Table V have been used extensively in actual practice, and have been found to give good results when used with judgment. The table gives the heat losses through different thicknesses of walls, doors, windows, etc., in B. T. U., per square foot of surface per hour, for varying differences in inside and outside temperatures.

In computing the heat loss through walls, only those exposed to the outside air are considered.

In order to make the use of the table clear, we shall give a number of examples illustrating its use:

Example 1. Assuming an inside temperature of 70°, what will be the heat loss from a room having an exposed wall surface of 200 square feet and a glass surface of 50 square feet, when the outside temperature is zero? The wall is of brick, 16 inches in thickness, and has a southern exposure; the windows are single; and the construction is of the best, so that no account need be taken of leakage

We find from Table V, that the factor for a 16-inch brick wall with a difference in temperature of 70° is 19, and that for glass (single window) under the same condition is 85; therefore,

$$\begin{array}{lcl}
\text{Loss through walls} & = 200 \times 19 = & 3{,}800 \\
\text{Loss through windows} & = \;\; 50 \times 85 = & 4{,}250 \\
\hline
\text{Total loss per hour} & = & 8{,}050\ \text{B.T.U.}
\end{array}$$

Example 2. A room 15 ft. square and 10 ft. high has two exposed walls, one toward the north, and the other toward the west. There are 4 windows, each 3 feet by 6 feet in size. The two in the north wall are double, while the

other two are single. The walls are of brick, 20 inches in thickness. With an inside temperature of 70°, what will be the heat loss per hour when it is 10° below zero?

Total exposed surface = 15 × 10 × 2 = 300
Glass surface = 3 × 6 × 4 = 72

Net wall surface = 228

Difference between inside and outside temperature 80°.
Factor for 20-inch brick wall is 18.
Factor for single window is 93.
Factor for double window is 62.
The heat losses are as follows:
Wall, 228 × 18 = 4,104
Single windows, 36 × 93 = 3,348
Double windows, 36 × 62 = 2,232

9,684 B. T. U.

As one side is toward the north, and the other toward the west, the actual exposure is N. W. Looking in Table VI, we find the correction factor for this exposure to be 1.26; therefore the total heat loss is

9,684 × 1.26 = 12,201.84 B. T. U.

Example 3. A dwelling-house of fair wooden construction measures 160 ft. around the outside; it has 2 stories, each 8 ft. in height; the windows are single, and the glass surface amounts to one-fifth the total exposure; the attic and cellar are unwarmed. If 8,000 B. T. U. are utilized from each pound of coal burned in the furnace, how many pounds will be required per hour to maintain a temperature of 70° when it is 20° above zero outside?

Total exposure = 160 × 16 = 2,560
Glass surface = 2,560 ÷ 5 = 512

Net wall = 2,048

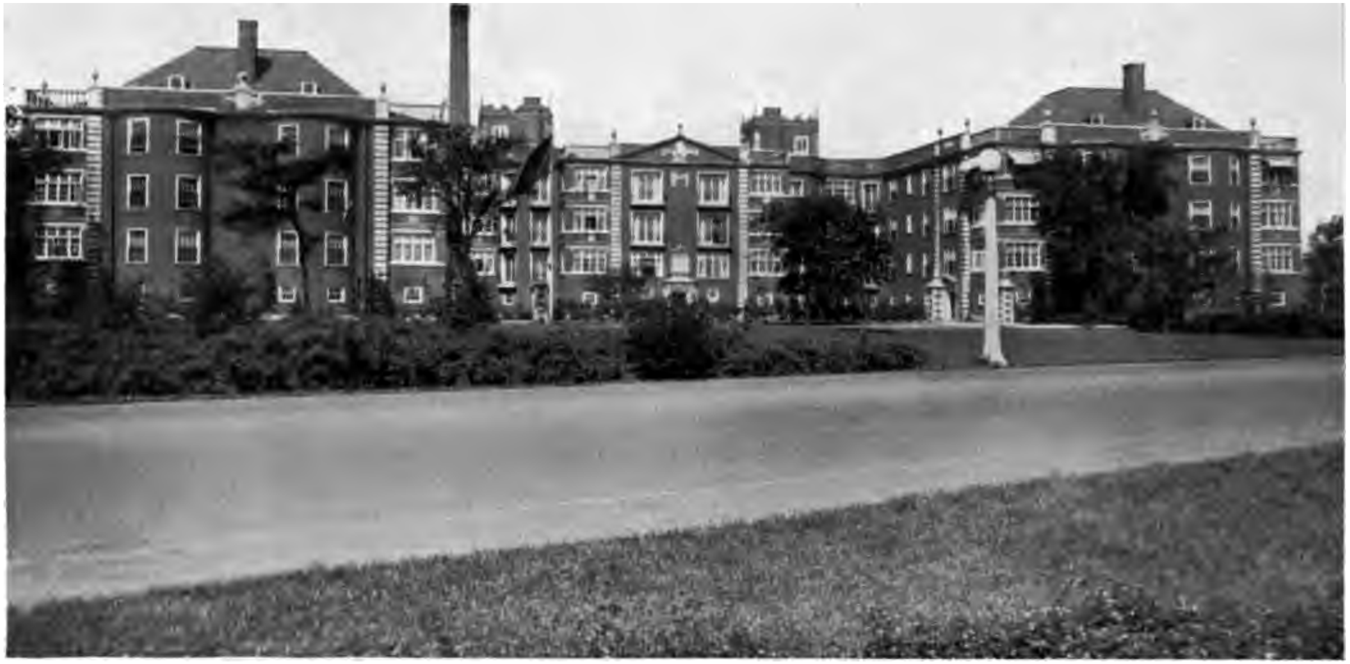
Temperature difference = 70 − 20 = 50°
Wall 2,048 × 13 = 26,624
Glass 512 × 60 = 30,720

57,344 B. T. U.

As the building is exposed on all sides, the factor for exposure will be the average of those for N., E., S., and W., or

(1.32 + 1.12 + 1.0 + 1.20) ÷ 4 = 1 16

The house has a cold cellar and attic, so we must increase the heat loss



THE CHASE APARTMENTS ON SHERIDAN ROAD, CHICAGO
Schmidt, Garden and Martin, Architects, Chicago

10 per cent for each of the first two conditions, and 20 per cent for the last. Making these corrections we have:

57,344 × 1.16 × 1.10 × 1.10 × 1.20 = 96,338 B. T. U.

If one pound of coal furnishes 8,000 B. T. U., then 96,338 ÷ 8,000 = 12 pounds of coal per hour required to warm the building to 70° under the conditions stated.

Approximate Method. For dwelling-houses of the average construction, the following simple method for calculating the heat loss may be used. Multiply the total exposed surface by 45, which will give the heat loss in B. T. U. per hour for an inside temperature of 70° in zero weather.

This factor is obtained in the following manner: Assume the glass surface to be one-sixth the total exposure, which is an average proportion. Then each square foot of exposed surface consists one-sixth of glass and five-sixths of wall, and the heat loss for 70° difference in temperature would be as follows:

$$\begin{aligned} \text{Wall } \frac{5}{6} \times 19 &= 15.8 \\ \text{Glass } \frac{1}{6} \times 85 &= \underline{14.1} \\ & 29.9 \end{aligned}$$

Increasing this 20 per cent for leakage, 16 per cent for exposure, and 10 per cent for cold ceilings, we have:

$$29.9 \times 1.20 \times 1.16 \times 1.10 = 45.$$

The loss through floors is considered as being offset by including the kitchen walls of a dwelling-house, which are warmed by the range, and which would not otherwise be included if computing the size of a furnace or boiler for heating.

If the heat loss is required for outside temperatures other than zero, multiply by 50 for 10 degrees below, and by 40 for 10 degrees above zero.

This method is convenient for approximations in the case of dwelling-houses; but the more exact method should be used for other types of buildings, and in all cases for computing the heating surface for separate rooms. *When calculating the heat loss from isolated rooms, the cold inside walls as well as the outside must be considered.*

The loss through a wall next to a cold attic or other unwarmed space may in general be taken as about two-thirds that of an outside wall.

Heat Loss by Ventilation. One B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees at average temperatures and pressures, or will raise 55 cubic feet 1 degree, so that the heat required for the ventilation of any room can be found by the following formula:

$$\frac{\text{Cu. ft. of air per hour} \times \text{Number of degrees rise}}{55} = \text{B. T. U. required.}$$

To compute the heat loss for any given room which is to be ventilated, first find the loss through walls and windows, and correct for exposure and leakage; then compute the amount required for ventilation as above, and take the sum of the two. An inside temperature of 70° is always assumed unless otherwise stated.

Examples. What quantity of heat will be required to warm 100,000 cubic feet of air to 70° for ventilating purposes when the outside temperature is 10 below zero?

$$100{,}000 \times 80 \div 55 = 145{,}454 \text{ B. T. U.}$$

How many B. T. U. will be required per hour for the ventilation of a church seating 500 people, in zero weather?

Referring to Table III, we find that the total air required per hour is $1{,}200 \times 500 = 600{,}000$ cu. ft.; therefore $600{,}000 \times 70 \div 55 = 763{,}636$ B. T. U.

The factor $\frac{\text{Rise in Temperature}}{55}$ is approximately 1.1 for 60°, 1.3 for 70°, and 1.5 for 80°. Assuming a temperature of 70° for the entering air, we may multiply the air-volume supplied for ventilation by 1.1 for an outside temperature of 10° above 0, by 1.3 for zero, and by 1.5 for 10° below zero—which covers the conditions most commonly met with in practice.

EXAMPLES FOR PRACTICE

1. A room in a grammar school 28 ft. by 32 ft. and 12 feet high is to accommodate 50 pupils. The walls are of brick 16 inches in thickness; and there are 6 single windows in the room, each 3 ft. by 6 ft.; there are warm rooms above and below; the exposure is S. E. How many B. T. U. will be required per hour for warming the room, and how many for ventilation, in zero weather, assuming the building to be of average construction?

ANS. 22,056 + for warming; 152,727 + for ventilation.

2. A stone church seating 400 people has walls 20 inches in thickness. It has a wall exposure of 5,000 square feet, a glass expos-

are (single windows) of 600 square feet, and a roof exposure of 7,000 square feet; the roof is of 2-inch pine plank, and the factor for heat loss may be taken the same as for a 2-inch wooden door. The floor is of wood on brick arches, and has an area of 4,000 square feet. The building is exposed on all sides, and is of first-class construction. What will be the heat required per hour for both warming and ventilation when the outside temperature is 20° above zero?

ANS. 296,380 for warming; 436,363 + for ventilation.

3. A dwelling-house of average wooden construction measures 200 feet around the outside, and has 3 stories, each 9 feet high. Compute the heat loss by the approximate method when the temperature is 10° below zero.

ANS. 270,000 B. T. U. per hour.

FURNACE HEATING

In construction, a furnace is a large stove with a combustion chamber of ample size over the fire, the whole being inclosed in a casing of sheet iron or brick. The bottom of the casing is provided with a cold-air inlet, and at the top are pipes which connect with registers placed in the various rooms to be heated. Cold, fresh air is brought from out of doors through a pipe or duct called the *cold-air box;* this air enters the space between the casing and the furnace near the bottom, and, in passing over the hot surfaces of the fire-pot and combustion chamber, becomes heated. It then rises through the warm-air pipes at the top of the casing, and is discharged through the registers into the rooms above.

As the warm air is taken from the top of the furnace, cold air flows in through the cold-air box to take its place. The air for heating the rooms does not enter the combustion chamber.

Fig. 5 shows the general arrangement of a furnace with its connecting pipes. The cold-air inlet is seen at the bottom, and the hot-air pipes at the top; these are all provided with dampers for shutting off or regulating the amount of air flowing through them. The feed or fire door is shown at the front, and the ash door beneath it; a *water-pan* is placed inside the casing, and furnishes moisture to the warm air before passing into the rooms; water is either poured into the pan through an opening in the front, provided for this purpose, or is supplied automatically through a pipe.

The fire is regulated by means of a draft slide in the ash door, and a cold-air or regulating damper placed in the smoke-pipe. Clean-out doors are placed at different points in the casing for the removal of ashes and soot. Furnaces are made either of cast iron, or of wrought-iron plates riveted together and provided with brick-lined firepots.

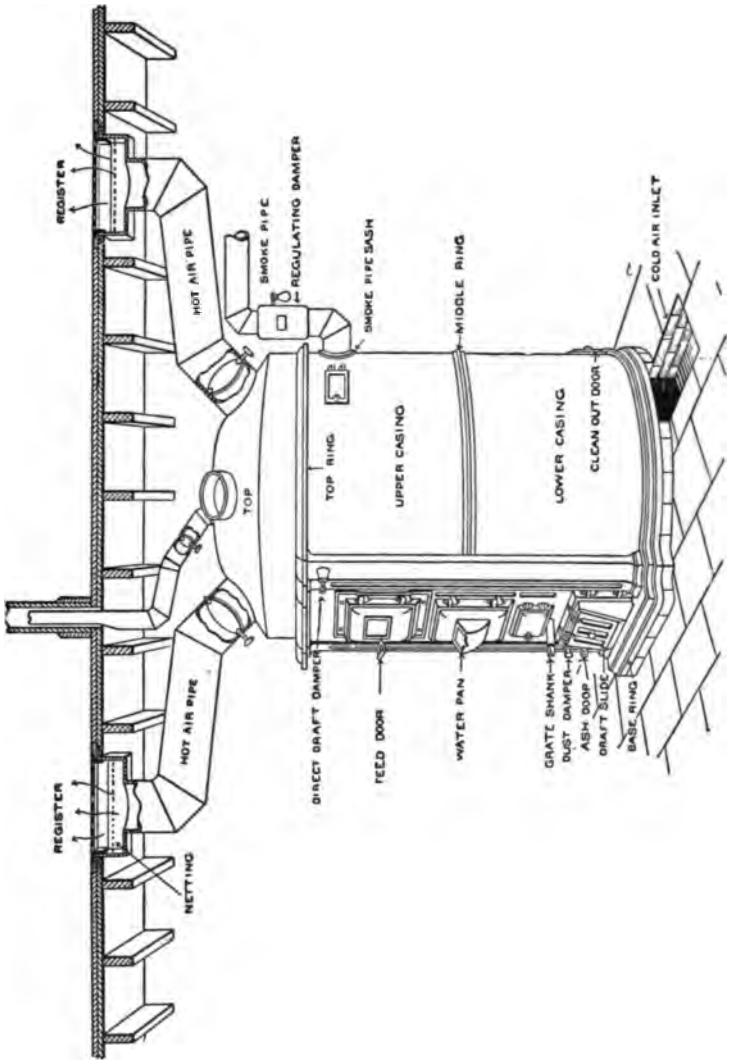


Fig. 5. General Arrangement of Details of a Hot-Air Furnace, with Connecting Pipes.

Types of Furnaces. Furnaces may be divided into two general types known as *direct-draft* and *indirect-draft.* Fig. 6 shows in section a common form of *direct-draft* furnace; the better class have a radiator, generally placed at the top, through which the gases pass before reaching the smoke-pipe. They have but one damper, usually combined with a cold-air check. Many of the cheaper direct-draft furnaces have no radiator at all, the gases passing directly into the smoke-pipe and carrying away much heat that should be utilized.

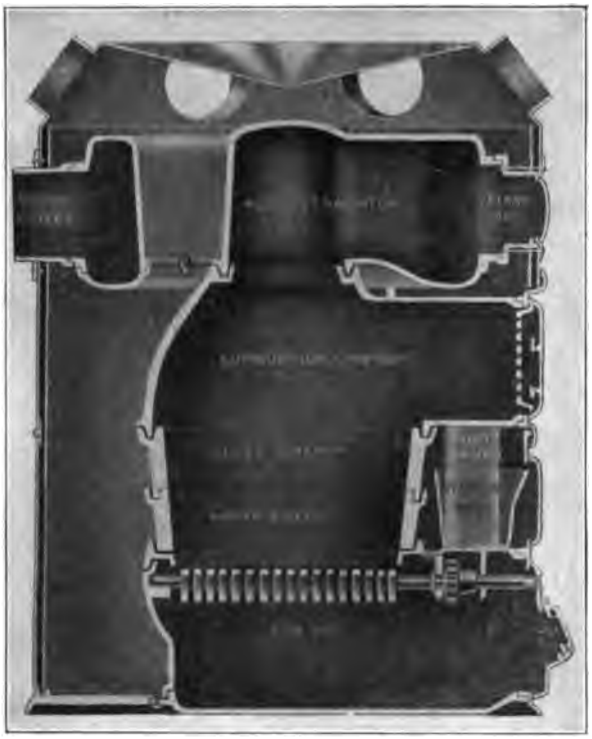


Fig. 6. Section through Direct-Draft Furnace.
Courtesy of Fuller-Warren Company, Milwaukee, Wisconsin.

The furnace shown in Fig. 6 is made of cast iron and has a large radiator at the top; the smoke connection is shown at the rear.

Fig. 7 represents another form of direct-draft furnace. In this case the radiator is made of sheet-steel plates riveted together with tubular flues passing through it.

In the ordinary *indirect-draft* type of furnace (see Fig. 8), the gases pass downward through flues to a radiator located near the base, thence upward through another flue to the smoke-pipe. In addition to the damper in the smoke-pipe, a direct-draft damper is required to give direct connection with the funnel when coal is first put on, to facilitate the escape of gas to the chimney. When the chimney draft is weak, trouble from gas is more likely to be experienced with furnaces of this type than with those having a direct draft.

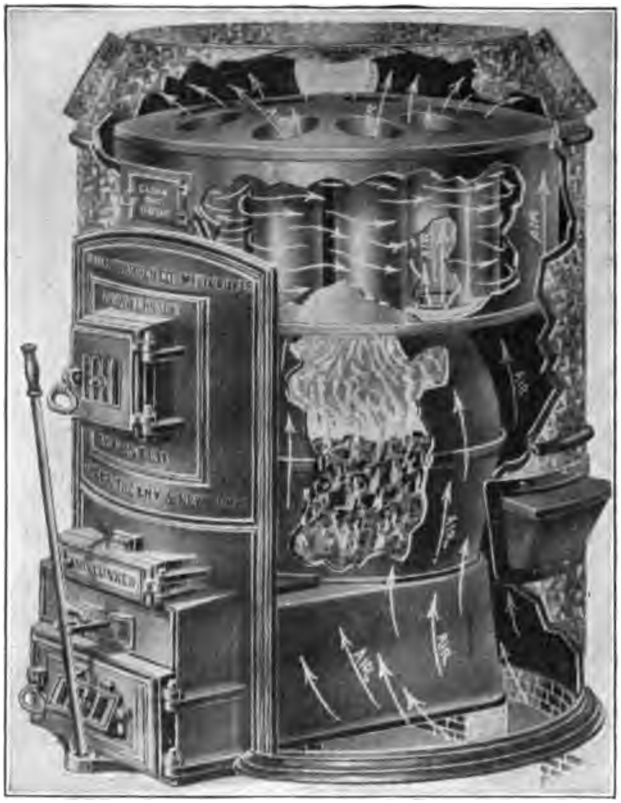


Fig. 7. Stewart "B" Direct-Draft Furnace with Tubular Steel Radiator. Portable Form for Hard or Soft Coal.
Courtesy of Fuller-Warren Company, Milwaukee, Wisconsin.

Grates. No part of a furnace is of more importance than the grates. The plain grate rotating about a center pin was for a long time the one most commonly used. These grates were usually provided with a clinker door for removing any refuse too large to pass between the grate bars. The action of such grates tends to leave a cone of ashes in the center of the fire causing it to burn more freely around the edges. A better form of grate is the revolving triangular pattern, which is now used in many of the leading furnaces. It consists of a series of triangular bars having teeth. The bars are connected by gears, and are turned by means of a detachable lever. If properly used, this grate will cut a slice of ashes and clinkers from under the entire fire with little, if any loss of unconsumed coal.

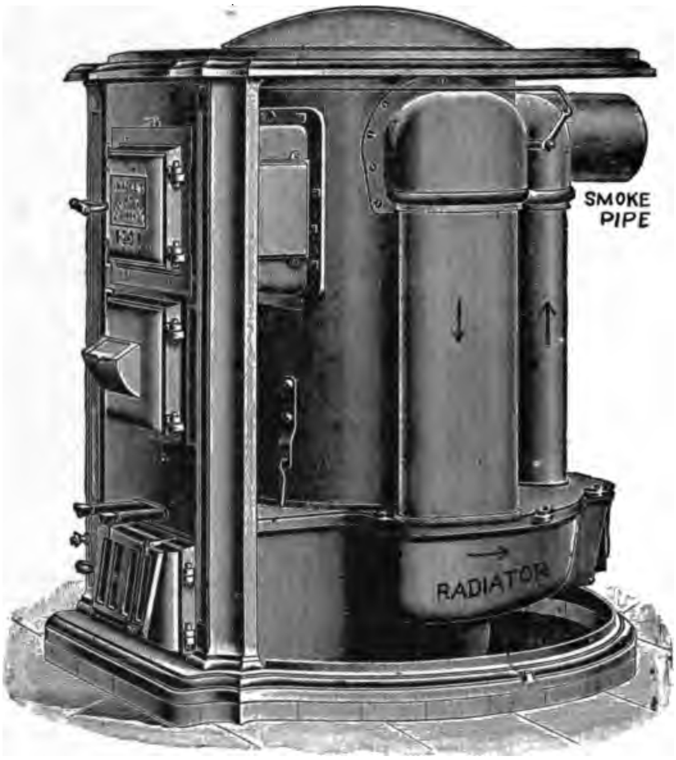


Fig. 8. Indirect-Draft Type of Furnace. Gases Pass Downward to Radiator at Bottom, Thence Upward to Smoke-Pipe.

The Firepot. Firepots are generally made of cast iron or of steel plate lined with firebrick. The depth ranges from about 12 to 18 inches. In cast-iron furnaces of the better class, the firepot is made very heavy, to insure durability and to render it less likely to become red-hot. The firepot is sometimes made in two pieces, to reduce the liability to cracking. The heating surface is sometimes increased by corrugations, pins, or ribs.

A firebrick lining is necessary in a wrought-iron or steel furnace to protect the thin shell from the intense heat of the fire. Since brick-lined firepots are much less effective than cast-iron in transmitting heat, such furnaces depend to a great extent for their efficiency on the heating surface in the dome and radiator; and this, as a rule, is much greater than in those of cast iron.

Cast-iron furnaces have the advantage when coal is first put on (and the drop flues and radiator are cut out by the direct damper) of still giving off heat from the firepot, while in the case of brick linings very little heat is given off in this way, and the rooms are likely to become somewhat cooled before the fresh coal becomes thoroughly ignited.

Combustion Chamber. The body of the furnace above the firepot, commonly called the *dome* or *feed section*, provides a combustion chamber. This chamber should be of sufficient size to permit the gases to become thoroughly mixed with the air passing up through the fire or entering through openings provided for the purpose in the feed door. In a well-designed furnace, this space should be somewhat larger than the firepot.

Radiator. The radiator, so called, with which all furnaces of the better class are provided, acts as a sort of reservoir in which the gases are kept in contact with the air passing over the furnace until they have parted with a considerable portion of their heat. Radiators are built of cast iron, of steel plate, or of a combination of the two. The former is more durable and can be made with fewer joints, but owing to the difficulty of casting radiators of large size, steel plate is commonly used for the sides.

The effectiveness of a radiator depends on its form, its heating surface, and the difference between the temperature of the gases and the surrounding air. Owing to the accumulation of soot, the bottom surface becomes practically worthless after the furnace has been in use a short time; surfaces, to be effective, must therefore be self-cleaning.

If the radiator is placed near the bottom of the furnace the gases are surrounded by air at the lowest temperature, which renders the radiator more effective for a given size than if placed near the top and surrounded by warm air. On the other hand, the cold air has a tendency to condense the gases, and the acids thus formed are likely to corrode the iron.

Heating Surface. The different heating surfaces may be described as follows: Firepot surface; surfaces acted upon by direct rays of heat from the fire, such as the dome or combustion chamber; gas- or smoke-heated surfaces, such as flues or radiators; and extended surfaces, such as pins or ribs. Surfaces unlike in character and location, vary greatly in heating power, so that, in making comparisons of different furnaces, we must know the kind, form, and location of the heating surfaces, as well as the area.

In some furnaces having an unusually large amount of surface, it will be found on inspection that a large part would soon become practically useless from the accumulation of soot. In others a large portion of the surface is lined with firebrick, or is so situated that the air-currents are not likely to strike it.

The ratio of grate to heating surface varies somewhat according to the size of furnace. It may be taken as 1 to 25 in the smaller sizes, and 1 to 15 in the larger.

Efficiency. One of the first items to be determined in estimating the heating capacity of a furnace, is its efficiency—that is, the proportion of the heat in the coal that may be utilized for warming. The efficiency depends chiefly on the area of the heating surface as compared with the grate, on its character and arrangement, and on the rate of combustion. The usual proportions between grate and heating surface have been stated. The rate of combustion required to maintain a temperature of 70° in the house, depends, of course, on the outside temperature. In very cold weather a rate of 4 to 5 pounds of coal per square foot of grate per hour must be maintained.

One pound of good anthracite coal will give off about 13,000 B. T. U., and a good furnace should utilize 70 per cent of this heat. The efficiency of an ordinary furnace is often much less, sometimes as low as 50 per cent.

In estimating the required size of a first-class furnace with good chimney draft, we may safely count upon a maximum combustion of 5 pounds of coal per square foot of grate per hour, and may assume that 8,000 B. T. U. will be utilized for warming purposes from each pound burned. This quantity corresponds to an efficiency of 60 per cent.

Heating Capacity. Having determined the heat loss from a building by the methods previously given, it is a simple matter to compute the size of grate necessary to burn a sufficient quantity of coal to furnish the amount of heat required for warming.

In computing the size of furnace, it is customary to consider the whole house as a single room, with four outside walls and a cold attic. The heat losses by conduction and leakage are computed, and increased 10 per cent for the cold attic, and 16 per cent for exposure. The heat delivered to the various rooms may be considered as being made up of two parts—*first,* that required to warm the outside air up to 70° (the temperature of the rooms); and *second,* the quantity which must be added to this to offset the loss by conduction and leakage. Air is usually delivered through the registers at a temperature of 120°, with zero conditions outside, in the best class of residence work; so that $\frac{70}{120}$ of the heat given to the entering air may be considered as making up the first part, mentioned above, leaving $\frac{50}{120}$ available for purely heating purposes. From this it is evident that the heat supplied to the entering air must be equal to $1 \div \frac{50}{120} = 2.4$ times that required to offset the loss by conduction and leakage.

Example. The loss through the walls and windows of a building is found to be 80,000 B. T. U. per hour in zero weather. What will be the size of furnace required to maintain an inside temperature of 70 degrees?

From the above, we have the total heat required, equal to $80{,}000 \times 2.4 = 192{,}000$ B. T. U. per hour. If we assume that 8,000 B. T. U. are utilized per pound of coal, then $192{,}000 \div 8{,}000 = 24$ pounds of coal required per hour; and if 5 pounds can be burned on each square foot of grate per hour, then $\frac{24}{5} = 4.8$ square feet required. A grate 30 inches in diameter has an area of 4.9 square feet, and is the size we should use.

When the outside temperature is taken as 10° below zero, multiply by 2.6 instead of 2.4; and multiply by 2.8 for 20° below.

Table VII will be found useful in determining the diameter of firepot required.

TABLE VII

Firepot Dimensions

Average Diameter of Grate, in Inches	Area in Square Feet
18	1.77
20	2.18
22	2.64
24	3.14
26	3.69
28	4.27
30	4.91
32	5.58

EXAMPLES FOR PRACTICE

1. A brick apartment house is 20 feet wide, and has 4 stories, each being 10 feet in height. The house is one of a block, and is exposed only at the front and rear. The walls are 16 inches thick, and the block is so sheltered that no correction need be made for exposure. Single windows make up $\frac{1}{8}$ the total exposed surface. Figure for cold attic but warm basement. What area of grate surface will be required for a furnace to keep the house at a temperature of 70° when it is 10° below zero outside? Ans. 3.5 square feet.

2. A house having a furnace with a firepot 30 inches in diameter, is not sufficiently warmed, and it is decided to add a second furnace to be used in connection with the one already in. The heat loss from the building is found by computation to be 133,600 B. T. U. per hour, in zero weather. What diameter of firepot will be required for the extra furnace? Ans. 24 inches.

Location of Furnace. A furnace should be so placed that the warm-air pipes will be of nearly the same length. The air travels most readily through pipes leading toward the sheltered side of the house and to the upper rooms. Therefore pipes leading toward the north or west, or to rooms on the first floor, should be favored in regard to length and size. The furnace should be placed somewhat to the north or west of the center of the house, or toward the points of compass from which the prevailing winds blow.

Smoke-Pipes. Furnace smoke-pipes range in size from about 6 inches in the smaller sizes to 8 or 9 inches in the larger ones. They are generally made of galvanized iron of No. 24 gauge or heavier. The pipe should be carried to the chimney as directly as possible, avoiding bends which increase the resistance and diminish the draft. Where a smoke-pipe passes through a partition, it should be protected by a soapstone or double-perforated metal collar having a diameter at least 8 inches greater than that of the pipe. The top of the smoke-pipe should not be placed within 8 inches of unprotected beams, nor less than 6 inches under beams protected by asbestos or plaster with a metal shield beneath. A collar to make tight connection with the chimney should be riveted to the pipe about 5 inches from the end, to prevent the pipe being pushed too far into the flue. Where the pipe is of unusual length, it is well to cover it to prevent loss of heat and the condensation of smoke.

Chimney Flues. Chimney flues, if built of brick, should have walls 8 inches in thickness, unless terra-cotta linings are used, when only 4 inches of brickwork is required. Except in small houses where an 8 by 8-inch flue may be used, the nominal size of the smoke flue should be at least 8 by 12-inches, to allow for contractions or offsets. A clean-out door should be placed at the bottom of the flue, for removing ashes and soot. A square flue cannot be reckoned at its full area, as the corners are of little value. To avoid down drafts, the top of the chimney must be carried above the highest point of the roof unless provided with a suitable hood or top.

Cold-Air Box. The cold-air box should be large enough to supply a volume of air sufficient to fill all the hot-air pipes at the same time. If the supply is too small, the distribution is sure to be unequal, and the cellar will become overheated from lack of air to carry away the heat generated.

If a box is made too small, or is throttled down so that the volume of air entering the furnace is not large enough to fill all the pipes, it will be found that those leading to the less exposed side of the house or to the upper rooms will take the entire supply, and that additional air to supply the deficiency will be drawn down through registers in rooms less favorably situated. It is common practice to make the area of the cold-air box three-fourths the combined area of the hot-air pipes. The inlet should be placed where the prevailing cold winds will blow into it; this is commonly on the north or west side of the house. If it is placed on the side away from the wind, warm air from the furnace is likely to be drawn out through the cold-air box.

Whatever may be the location of the entrance to the cold-air box, changes in the direction of the wind may take place which will bring the inlet on the wrong side of the house. To prevent the possibility of such changes affecting the action of the furnace, the cold-air box is sometimes extended through the house and left open at both ends, with check-dampers arranged to prevent back-drafts. These checks should be placed some distance from the entrance, to prevent their becoming clogged with snow or sleet.

The cold-air box is generally made of matched boards; but galvanized iron is much better; it costs more than wood, but is well worth the extra expense on account of tightness, which keeps the dust and ashes from being drawn into the furnace casing to be discharged through the registers into the rooms above.

The cold-air inlet should be covered with galvanized wire netting with a mesh of at least three-eighths of an inch. The frame to which it is attached should not be smaller than the inside dimensions of the cold-air box. A door to admit air from the cellar to the cold-air box is generally provided. As a rule, air should be taken from this source, only when the house is temporarily unoccupied or during high winds.

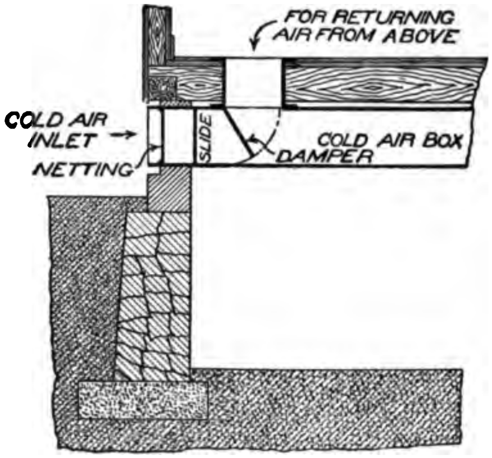


Fig 9. Common Method of Connecting Return Duct to Cold-Air Box.

Return Duct. In some cases it is desirable to return air to the furnace from the rooms above, to be reheated. Ducts for this purpose are common in places where the winter temperature is frequently below zero. Return ducts when used, should be in addition to the regular cold-air box. Fig. 9 shows a common method of making the connection between the two. By proper adjustment of the swinging damper, the air can be taken either from out of doors or through the register from the room above. The return register is often placed in the hallway of a house, so that it will take the cold air which rushes in when the door is opened and also that which may leak in around it while closed. Check-valves or flaps of light gossamer or woolen cloth should be placed between the cold-air box and the registers to prevent back-drafts during winds.

The return duct should not be used too freely at the expense of outdoor air, and its use is not recommended except during the night when air is admitted to the sleeping rooms through open windows.

Warm-Air Pipes. The required size of the warm-air pipe to any given room, depends on the heat loss from the room and on the volume of warm air required to offset this loss. Each cubic foot of air warmed from zero to 120 degrees brings into a room 2.2 B. T. U. We have already seen that in zero weather, with the air entering the registers at 120 degrees, only $\frac{50}{120}$ of the heat contained in the air is available for offsetting the losses by radiation and conduction, so that only $2.2 \times \frac{50}{120} = .9$ B. T. U. in each cubic foot of entering air can be utilized for warming purposes. Therefore, if we divide the computed heat loss in B. T. U. from a room, by .9, it will give the number of cubic feet of air at 120 degrees necessary to warm the room in zero weather.

As the outside temperature becomes colder, the quantity of heat brought in per cubic foot of air increases; but the proportion available for warming purposes becomes less at nearly the same rate, so

TABLE VIII

Warm-Air Pipe Dimensions

Diameter of Pipe, in Inches	Area in Square Inches	Area in Square Feet
6	28	.196
7	38	.267
8	50	.349
9	64	.442
10	79	.545
11	95	.660
12	113	.785
13	133	.922
14	154	1.07
15	177	1.23
16	201	1.40

that for all practical purposes we may use the figure .9 for all usual conditions. In calculating the size of pipe required, we may assume maximum velocities of 260 and 380 feet per minute for rooms on the first and second floors respectively. Knowing the number of cubic feet of air per minute to be delivered, we can divide it by the velocity, which will give us the required area of the pipe in square feet.

Round pipes of tin or galvanized iron are used for this purpose. Table VIII will be found useful in determining the required diameters of pipe in inches.

Example. The heat loss from a room on the second floor is 18,000 B. T. U. per hour. What diameter of warm-air pipe will be required?

18,000 ÷ .9 = 20,000 = cubic feet of air required per hour. 20,000 ÷ 60 = 333 per minute. Assuming a velocity of 380 feet per minute, we have 333 ÷ 380 = .87 square foot, which is the area of pipe required. Referring to Table VIII, we find this comes between a 12-inch and a 13-inch pipe, and the larger size would probably be chosen.

EXAMPLES FOR PRACTICE

1. A first-floor room has a computed loss of 27,000 B. T. U. per hour when it is 10° below zero. The air for warming is to enter through two pipes of equal size, and at a temperature of 120 degrees. What will be the required diameter of the pipes?

Ans. 14 inches.

2. If in the above example the room had been on the second floor, and the air was to be delivered through a single pipe, what diameter would be required?

Ans. 16 inches.

Since long horizontal runs of pipe increase the resistance and loss of heat, they should not in general be over 12 or 14 feet in length. This applies especially to pipes leading to rooms on the first floor, or to those on the cold side of the house. Pipes of excessive length should be increased in size because of the added resistance.

Figs. 10 and 11 show common methods of running the pipes in the basement. The first gives the best results, and should be used where the basement is of sufficient height to allow it. A damper should be placed in each pipe near the furnace, for regulating the flow of air to the different rooms, or for shutting it off entirely when desired.

While round pipe risers give the best results, it is not always possible to provide a sufficient space for them, and flat or oval pipes are substituted. When vertical pipes must be placed in single partitions, much better results will be obtained if the studding can be made 5 or 6 inches deep instead of 4 as is usually done. Flues should never in any case be made less than 3½ inches in depth. Each room should be heated by a separate pipe. In some cases, however, it is allowable to run a single riser to heat two unimportant rooms on an upper floor. A clear space of at least ½ inch should be left between the risers and studs, and the latter should be carefully tinned, and the

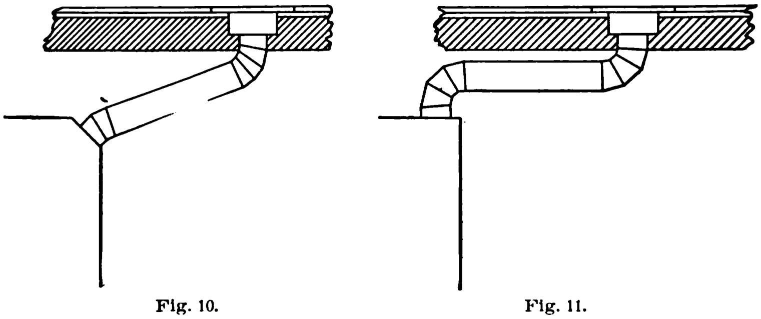


Fig. 10. Fig. 11.

Common Methods of Running Hot-Air Pipes in Basement. Method Shown in Fig. 10 is Preferable where Feasible.

TABLE IX

Dimensions of Oval Pipes

Dimension of Pipe	Area in Square Inches
6 ovaled to 5 in.	27
7 " " 4 "	31
7 " " 3½ "	29
7 " " 6 "	38
8 " " 5 "	43
9 " " 4 "	45
9 " " 6 "	57
9 " " 5 "	51
10 " " 3½ "	46
11 " " 4 "	58
12 " " 3½ "	55
10 " " 6 "	67
11 " " 5 "	67
14 " " 4 "	76
15 " " 3½ "	73
12 " " 6 "	85
12 " " 5 "	75
19 " " 4 "	96
20 " " 3½ "	100

space between them on both sides covered with tin, asbestos, or wire lath.

Table IX gives the capacity of oval pipes. A 6-inch pipe ovaled to 5 means that a 6-inch pipe has been flattened out to a thickness of 5 inches, and column 2 gives the resulting area.

Having determined the size of round pipe required, an equivalent oval pipe can be selected from the table to suit the space available.

Registers. The registers which control the supply of warm air to the rooms, generally have a net area equal to two-thirds of their gross area. The net area should be from 10 to 20 per cent greater than the area of the pipe connected with it. It is common practice to use registers having the short dimensions equal to, and the long dimensions about one-half greater than, the diameter of the pipe. This would give standard sizes for different diameters of pipe, as listed in Table X.

TABLE X
Sizes of Registers for Different Sizes of Pipes

DIAMETER OF PIPE	SIZE OF REGISTER
6 in.	6 × 10 in.
7 "	7 × 10 "
8 "	8 × 12 "
9 "	9 × 14 "
10 "	10 × 15 "
11 "	11 × 16 "
12 "	12 × 17 "
13 "	14 × 20 "
14 "	14 × 22 "
15 "	15 × 22 "
16 "	16 × 24 "

Combination Systems. A combination system for heating by hot air and hot water consists of an ordinary furnace with some form of surface for heating water, placed either in contact with the fire or suspended above it. Fig. 12 shows a common arrangement where part of the heating surface forms a portion of the lining to the firepot and the remainder is above the fire.

Care must be taken to proportion properly the work to be done by the air and the water; else one will operate at the expense of the other. One square foot of heating surface in contact with the fire is capable of supplying from 40 to 50 square feet of radiating surface, and one square foot suspended over the fire will supply from 15 to 25 square feet of radiation.

The value or efficiency of the heating surface varies so widely in different makes that it is best to state the required conditions to the manufacturers and have them proportion the surfaces as their experience has found best for their particular type of furnace.

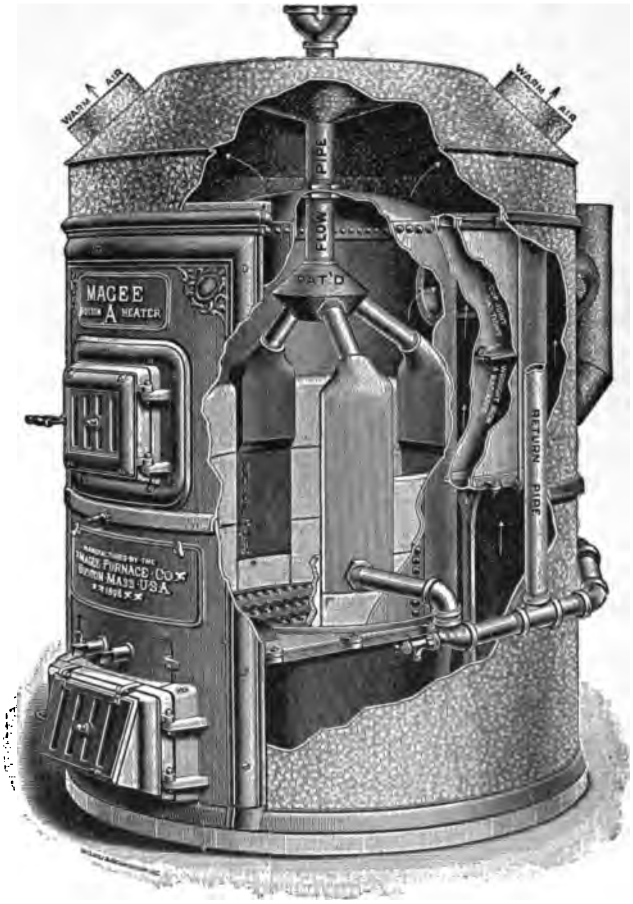


Fig. 12. Combination Furnace, for Heating by Both Hot Air and Hot Water.

Care and Management of Furnaces. The following general rules apply to the management of all hard coal furnaces.

The fire should be thoroughly shaken once or twice daily in cold weather. It is well to keep the firepot heaping full at all times. In this way a more even temperature may be maintained, less attention is required, and no more coal is burned than when the pot is only partly filled. In mild weather the mistake is frequently made of carrying a thin fire, which requires frequent attention and is likely to die out. Instead, to diminish the temperature in the house, keep the firepot full and allow ashes to accumulate on the grate (not under it) by shaking less frequently or less vigorously. The ashes will hold the heat and render it an easy matter to maintain and control the fire. When feeding coal on a low fire, open the drafts and neither rake nor shake the fire till the fresh coal becomes ignited. The air supply to the fire is of the greatest importance. An insufficient amount results in incomplete combustion and a great loss of heat. To secure proper combustion, the fire should be controlled principally by means of the ash-pit through the ash-pit door or slide.

The smoke-pipe damper should be opened only enough to carry off the gas or smoke and to give the necessary draft. The openings in the feed door act as a check on the fire, and should be kept closed during cold weather, except just after firing, when with a good draft they may be partly opened to increase the air-supply and promote the proper combustion of the gases.

Keep the ash-pit clear to avoid warping or melting the grate. The cold-air box should be kept wide open except during winds or when the fire is low. At such times it may be partly, but never completely closed. Too much stress cannot be laid on the importance of a sufficient air-supply to the furnace. It costs little if any more to maintain a comfortable temperature in the house night and day than to allow the rooms to become so cold during the night that the fire must be forced in the morning to warm them up to a comfortable temperature.

In case the warm air fails at times to reach certain rooms, it may be forced into them by temporarily closing the registers in other rooms. The current once established will generally continue after the other registers have been opened.

It is best to burn as hard coal as the draft will warrant. Egg size is better than larger coal, since for a given weight small lumps expose more surface and ignite more quickly than larger ones. The furnace and smoke-pipe should be thoroughly cleaned once a year.

This should be done just after the fire has been allowed to go out in the spring.

STEAM BOILERS

Types. The boilers used for heating are the same as have already been described for power work. In addition there is the cast-iron sectional boiler, used almost exclusively for dwelling-houses.

Tubular Boilers. Tubular boilers are largely used for heating purposes, and are adapted to all classes of buildings except dwelling-houses and the special cases mentioned later, for which sectional boilers are preferable. A *boiler horse-power* has been defined as the evaporation of 34½ pounds of water from and at a temperature of 212 degrees, and in doing this 33,317 B. T. U. are absorbed, which are again given out when the steam is condensed in the radiators. Hence to find the boiler H. P. required for warming any given building, we have only to compute the heat loss per hour by the methods already given, and divide the result by 33,330. It is more common to divide by the number 33,000, which gives a slightly larger boiler and is on the side of safety.

The commercial horse-power of a well-designed boiler is based upon its heating surface; and for the best economy in heating work, it should be so proportioned as to have about 1 square foot heating of surface for each 2 pounds of water to be evaporated from and at 212 degrees F. This gives $34.5 \div 2 = 17.2$ square feet of heating surface per horse-power, which is generally taken as 15 in practice. Makers of tubular boilers commonly rate them on a basis of 12 square feet of heating surface per horse-power. This is a safe figure under the conditions of power work, where skilled firemen are employed and where more care is taken to keep the heating surfaces free from soot and ashes. For heating plants, however, it is better to rate the boilers upon 15 square feet per horse-power as stated above.

There is some difference of opinion as to the proper method of computing the heating surface of tubular boilers. In general, all surface is taken which is exposed to the hot gases on one side and to the water on the other. A safe rule, and the one by which Table XII is computed, is to take ½ the area of the shell, ⅔ of the rear head, less the tube area, and the interior surface of all the tubes.

The required amount of grate area, and the proper ratio of heating surface to grate area, vary a good deal, depending on the character of the fuel and on the chimney draft. By assuming the probable rates of combustion and evaporation, we may compute the required grate area for any boiler from the formula:

$$S = \frac{H.P. \times 34.5}{.E \times C},$$

in which

S = Total grate area, in square feet;
E = Pounds of water evaporated per pound of coal;
C = Pounds of coal burned per square foot of grate per hour.

Table XI gives the approximate grate area per H. P. for different rates of evaporation and combustion as computed by the above equation.

TABLE XI

Grate Area per Horse-Power for Different Rates of Evaporation and Combustion

Pounds of Steam per Pound of Coal	Pounds of Coal Burned per Square Foot of Grate per Hour		
	8 lbs.	**10 lbs.**	**12 lbs.**
	Square Feet of Grate Surface per Horse-Power		
10	.43	.35	.28
9	.48	.38	.32
8	.54	.43	.36
7	.62	.49	.41
6	.72	.58	.48

For example, with an evaporation of 8 pounds of steam per pound of coal, and a combustion of 10 pounds of coal per square foot of grate, .43 of a square foot of grate surface per H. P. would be called for.

The ratio of heating to grate surface in this type of boiler ranges from 30 to 40, and therefore allows under ordinary conditions a combustion of from 8 to 10 pounds of coal per square foot of grate. This is easily obtained with a good chimney draft and careful firing. The larger the boiler, the more important the plant usually, and the greater the care bestowed upon it, so that we may generally count on a higher rate of combustion and a greater efficiency as the size of the boiler increases. Table XII will be found very useful in determining the size of boiler required under different conditions. The grate area is computed for an evaporation of 8 pounds of water per pound

TABLE XII

Diameter of Shell in Inches	Number of Tubes	Diameter of Tubes in Inches	Length of Tubes in Feet	Horse-Power	Size of Grate in Inches	Size of Uptake in Inches	Size of Smoke-pipe in Sq. In
30	28	2½	6	8.5	24 x 36	10 x 14	140
			7	9.9	24 x 36	10 x 14	140
			8	11.2	24 x 36	10 x 14	140
			9	12.6	24 x 42	10 x 14	140
			10	14.0	24 x 42	10 x 14	140
36	34	2½	8	13.6	30 x 36	10 x 16	160
			9	15.8	30 x 42	10 x 18	180
			10	16.9	30 x 42	10 x 18	180
			11	18.6	30 x 48	10 x 20	200
			12	20.9	30 x 48	10 x 20	200
42	34	3	9	18.5	36 x 42	10 x 20	200
			10	20.5	36 x 42	10 x 20	200
			11	22.5	36 x 48	10 x 25	250
			12	24.5	36 x 48	10 x 25	250
			13	26.5	36 x 48	10 x 28	280
			14	28.5	36 x 54	10 x 28	280
48	44	3	10	30.4	42 x 48	10 x 28	280
			11	33.2	42 x 48	10 x 28	280
			12	35.7	42 x 54	10 x 32	320
			13	38.3	42 x 54	10 x 32	320
			14	40.8	42 x 60	10 x 36	360
			15	43.4	42 x 60	10 x 36	360
			16	45.9	42 x 60	10 x 36	360
54	54	3	11	34.6	48 x 54	10 x 38	380
			12	37.7	48 x 54	10 x 38	380
			13	40.8	48 x 54	10 x 38	380
			14	43.9	48 x 54	10 x 38	380
			15	47.0	48 x 60	10 x 40	400
			16	50.1	48 x 60	10 x 40	400
	46	3½	17	53.0	48 x 60	10 x 40	400
60	72	3	12	48.4	54 x 60	12 x 40	460
			13	52.4	54 x 60	12 x 40	460
			14	56.4	54 x 60	12 x 40	460
			15	60.4	54 x 66	12 x 42	500
			16	64.4	54 x 66	12 x 42	500
	64	3½	17	71.4	54 x 72	12 x 48	550
			18	75.6	54 x 72	12 x 48	550
66	90	3	14	70.1	60 x 66	12 x 48	500
			15	75.0	60 x 72	12 x 52	620
			16	80.0	60 x 72	12 x 52	620
	78	3½	17	86.0	60 x 78	12 x 56	670
			18	91.1	60 x 78	12 x 56	670
			19	96.2	60 x 78	12 x 56	670
	62	4	20	93.1	60 x 78	12 x 56	670
72	114	3	14	87.4	66 x 72	12 x 56	670
			15	93.6	66 x 72	12 x 56	670
			16	99.7	66 x 78	12 x 62	740
	98	3½	17	106.4	66 x 78	12 x 62	740
			18	112.6	66 x 84	12 x 66	790
			19	118.8	66 x 84	12 x 66	790
	72	4	20	107.3	66 x 84	12 x 66	790

of coal, which corresponds to an efficiency of about 60 per cent, and is about the average obtained in practice for heating boilers.

The areas of uptake and smoke-pipe are figured on a basis of 1 square foot to 7 square feet of grate surface, and the results given in round numbers. In the smaller sizes the relative size of smoke-pipe is greater. The rate of combustion runs from 6 pounds in the smaller sizes to 11½ in the larger. Boilers of the proportions given in the table, correspond well with those used in actual practice, and may be relied upon to give good results under all ordinary conditions.

Water-tube boilers are often used for heating purposes, but more especially in connection with power plants. The method of computing the required H. P. is the same as for tubular boilers.

Sectional Boilers. Fig. 13 shows a common form of cast-iron boiler. It is made up of slabs or sections, each one of which is connected by nipples with headers at the sides and top. The top header acts as a steam drum, and the lower ones act as mud drums; they also receive the water of condensation from the radiators. The gases from the fire pass backward and forward through flues and are finally taken off at the rear of the boiler.

Another common form of sectional boiler is shown in Fig. 14. It is made up of sections which increase the length like the one just described. These boilers have no drum connecting with the sections; but instead, each section connects with the adjacent one through openings at the top and bottom, as shown.

The ratio of heating to grate surface in boilers of this type ranges from 15 to 25 in the best makes. They are provided with the usual attachments, such as pressure-gauge, water-glass, gauge-cocks, and safety-valve; a low-pressure damper regulator is furnished for operating the draft doors, thus keeping the steam pressure practically constant. A pressure of from 1 to 5 pounds is usually carried on these boilers, depending upon the outside temperature. The usual setting is simply a covering of some kind of non-conducting material like plastic magnesia or asbestos, although some forms are enclosed in light brickwork.

In computing the required size, we may proceed in the same manner as in the case of a furnace. For the best types of house-heating boilers, we may assume a combustion of 5 pounds of coal per square foot of grate per hour, and an average efficiency of 60 per cent, which corresponds to 8,000 B. T. U. per pound of coal, available for useful work.

In the case of direct-steam heating, we have only to supply heat to offset that lost by radiation and conduction; so that the grate area may be found by dividing the computed heat loss per hour by 8,000, which gives the number of pounds of coal; and this in turn, divided by 5, will give the area of grate required. The most efficient rate of combustion will depend somewhat upon the ratio between the grate and heating surface. It has been found by experience that about ¼ of a pound of coal per hour for each square foot of heating surface gives the best results; so that, by knowing the ratio of heating surface to grate area for any make of heater, we can easily compute the most efficient rate of combustion, and from it determine the necessary grate area.

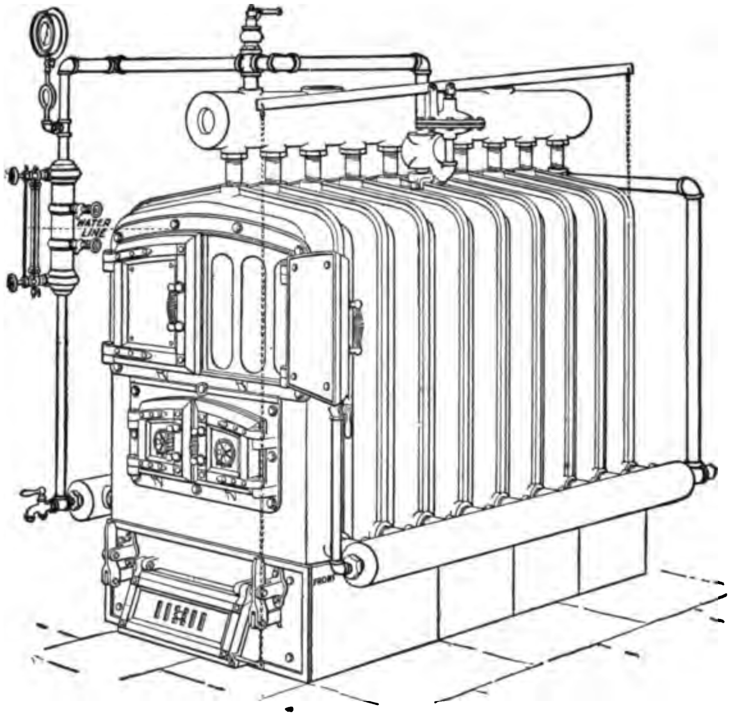


Fig. 13. Common Type of Cast-Iron Sectional Boiler. Note Headers at Sides and Top Acting as Drums.

For example, suppose the heat loss from a building to be 480,000 B. T. U. per hour, and that we wish to use a heater in which the ratio of heating surface to grate area is 24. What will be the most efficient rate of combustion and the required grate area? 480,000 ÷ 8,000 = 60 pounds of coal per hour, and 24÷4=6, which is the best rate of combustion to employ; therefore 60÷6=10, the grate area required.

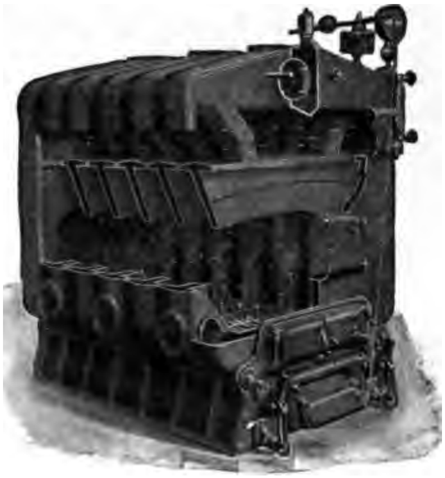


Fig. 14. Ideal Sectional 36-Inch Steam Boiler.
Courtesy of American Radiator Company.

There are many different designs of cast-iron boilers for low-pressure steam and hot-water heating. In general, boilers having a drum connected by nipples with each section give dryer steam and hold a steadier water-line than the second form, especially when forced above their normal capacity. The steam, in passing through the openings between successive sections in order to reach the outlet, is apt to carry with it more or less water, and to choke the openings, thus producing an uneven pressure in different parts of the boiler.

In the case of hot-water boilers this objection disappears.

For steam work the opening between the sections should be of good size, with an ample steam space above the water-line; and the nozzles for the discharge of steam should be located at frequent intervals.

EXAMPLES FOR PRACTICE

1. The heat loss from a building is 240,000 B. T. U. per hour, and the ratio of heating to grate area in the heater to be used is 20. What will be the required grate area? Ans. 6 sq. ft.

2. The heat loss from a building is 168,000 B. T. U. per hour, and the chimney draft is such that not over 3 pounds of coal per hour can be burned per square foot of grate. What ratio of heating to grate area will be necessary, and what will be the required grate area?
Ans. Ratio, 12. Grate area, 7 sq. ft.

Cast-iron sectional boilers are used for dwelling-houses, small schoolhouses, churches, etc., where low pressures are carried. They are increased in size by adding more slabs or sections. After a certain length is reached, the rear sections become less and less efficient, thus limiting the size and power.

Horse-Power for Ventilation. We already know that one B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees, or it will raise 100 cubic feet $\frac{1}{100}$ of 55 degrees, or $\frac{55}{100}$ of 1 degree; therefore, to raise 100 cubic feet 1 degree, it will take $1 \div \frac{55}{100}$, or $\frac{100}{55}$ B. T. U.; and to raise 100 cubic feet through 100 degrees, it will take $\frac{100}{55} \times 100$ B. T. U. In other words, the B. T. U. required to raise any given volume of air through any number of degrees in temperature, is equal to

$$\frac{\text{Volume of air in cubic ft.} \times \text{Degrees raised}}{55}$$

Example. How many B. T. U. are required to raise 100,000 cubic feet of air 70 degrees?

$$\frac{100{,}000 \times 70}{55} = 127{,}272 +$$

To compute the H. P. required for the ventilation of a building, we multiply the total air-supply, in cubic feet per hour, by the number of degrees through which it is to be raised, and divide the result by 55. This gives the B. T. U. per hour, which, divided by 33,000, will give the H. P. required. In using this rule, always take the air-supply in cubic feet per *hour*.

EXAMPLES FOR PRACTICE

1. The heat loss from a building is 1,650,000 B. T. U. per hour. There is to be an air-supply of 1,500,000 cubic feet per hour, raised through 70 degrees. What is the total boiler H. P. required?

Ans. 108.

2. A high school has 10 classrooms, each occupied by 50 pupils. Air is to be delivered to the rooms at a temperature of 70 degrees. What will be the total H. P. required to heat and ventilate the building when it is 10 degrees below zero, if the heat loss through walls and windows is 1,320,000 B. T. U. per hour? Ans. 106+.

DIRECT-STEAM HEATING

A system of direct-steam heating consists (1) of a furnace and boiler for the combustion of fuel and the generation of steam; (2) a system of pipes for conveying the steam to the radiators and for returning the water of condensation to the boiler; and (3) radiators or coils placed in the rooms for diffusing the heat.

Various types of boilers are used, depending upon the size and kind of building to be warmed. Some form of cast-iron sectional boiler is commonly used for dwelling-houses, while the tubular or water-tube boiler is more usually employed in larger buildings. Where the boiler is used for heating purposes only, a low steam-pressure of from 2 to 10 pounds is carried, and the condensation flows back by gravity to the boiler, which is placed below the lowest radiator. When, for any reason, a higher pressure is required, the steam for the heating system is made to pass through a reducing valve, and the condensation is returned to the boiler by means of a pump or return trap.

Types of Radiating Surface. The radiation used in direct-steam heating is made up of cast-iron radiators of various forms, of pipe radiators, and of circulation coils.

Cast-Iron Radiators. The general form of a cast-iron sectional radiator is shown in Fig. 15. Radiators of this type are made up of sections, the number depending upon the amount of heating surface required. Fig. 16 shows an intermediate section of a radiator of this type. It is simply a loop with inlet and outlet at the bottom. The end sections are the same, except that they have legs, as shown in Fig. 17. These sections are connected at the bottom by special nipples, so that steam entering at the end fills the bottom of the radiator, and, being lighter than the air, rises through the loops and forces the air downward and toward the farther end, where it is discharged through an air-valve placed about midway of the last section. For one-pipe steam work the *supply-leg* section is constructed with low-drip hub, and for two-pipe steam work, the *return-leg* section is constructed with low-drip hub.

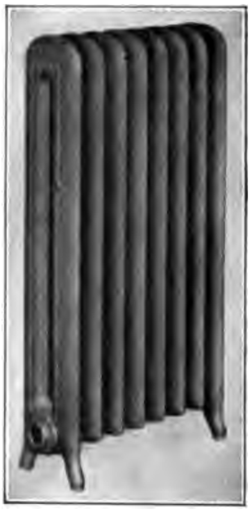


Fig. 15. Peerless 2-Column Cast-Iron Radiator.
Courtesy of American Radiator Company, Chicago.

There are many designs varying in height and width, to suit all conditions. The wall pattern shown in Fig. 18 is very convenient when it is desired to place the radiator above the floor, as in bathrooms, etc.; it is also a convenient form to place under the windows of halls and churches to counteract the effect of cold down drafts. It is adapted to nearly every place where the ordinary direct radiator can be used, and may be connected up in different ways to meet the various requirements.

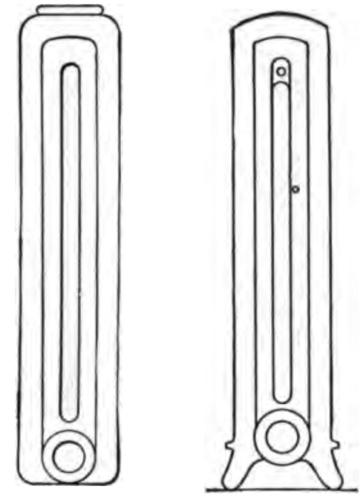


Fig. 16. Fig. 17.

Intermediate and End Sections of Radiator Shown in Fig. 15. The end sections (at right) have legs.

A low and moderately shallow radiator, with ample space for the circulation of air between the sections, is more efficient than a deep radiator with the sections closely packed together. One- and two-column radiators, so called, are preferable to three- and four-column, when there is sufficient space to use them.

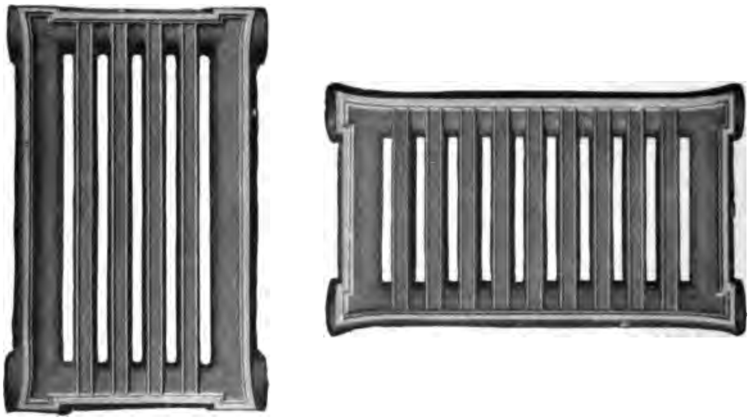


Fig. 18. Rococo Wall Radiators.
Courtesy of American Radiator Company, Chicago.

The standard height of a radiator is 36 or 38 inches, and, if possible, it is better not to exceed this.

For small radiators, it is better practice to use lower sections and increase the length; this makes the radiator slightly more efficient and gives a much better appearance.

To get the best results from wall radiators, they should be set out at least 1½ inches from the wall to allow a free circulation of air back of them. Patterns having cross-bars should be placed, if possible, with the bars in a vertical position, as their efficiency is impaired somewhat when placed horizontally.

Pipe Radiators. This type of radiator (see Fig. 19) is made up of wrought-iron pipes screwed into a cast-iron base. The pipes are either connected in pairs at the top by return bends, or each separate tube has a thin metal diaphragm passing up the center nearly to the top. It is necessary that a loop be formed, else a "dead end" would occur. This would become filled with air and prevent steam from entering, thus causing portions of the radiator to remain cold.

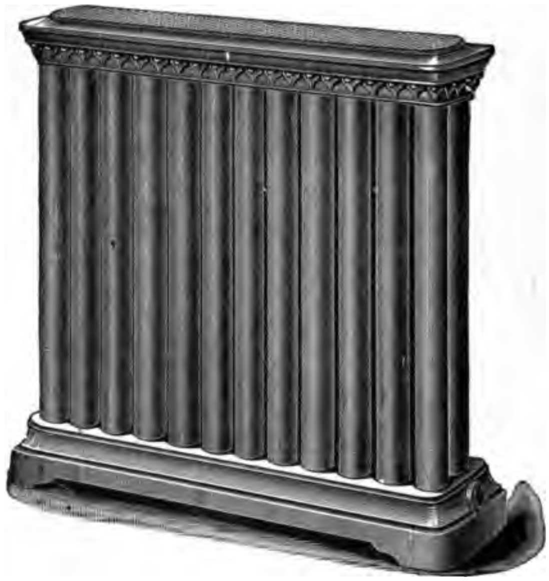


Fig. 19. Wrought-Iron Pipe Radiator.

Circulation Coils. These are usually made up of 1 or 1¼-inch wrought-iron pipe, and may be hung on the walls of a room by means of hook plates, or suspended overhead on hangers and rolls.

Fig. 20 shows a common form for schoolhouse and similar work; this coil is usually made of 1¼-inch pipe screwed into *headers* or *branch tees* at the ends, and is hung on the wall just below the windows. This is known as a *branch coil.* Fig. 21 shows a *trombone coil,* which is commonly used when the pipes cannot turn a corner, and where the entire coil must be placed upon one side of the room. Fig. 22

is called a *miter coil,* and is used under the same conditions as a trombone coil if there is room for the vertical portion. This form is not so pleasing in appearance as either of the other two, and is found only in factories or shops, where looks are of minor importance.

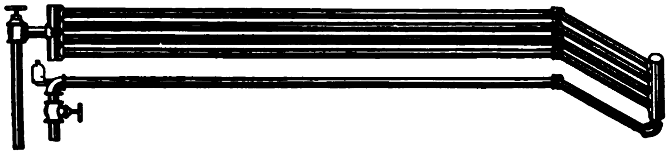


Fig. 20. Common Form of "Branch" Coil for Circulation of Direct Steam.

Overhead coils are usually of the miter form, laid on the side and suspended about a foot from the ceiling; they are less efficient than when placed nearer the floor, as the warm air stays at the ceiling and the lower part of the room is likely to remain cold. They are used only when wall coils or radiators would be in the way of fixtures, or when they would come below the water-line of the boiler if placed near the floor.

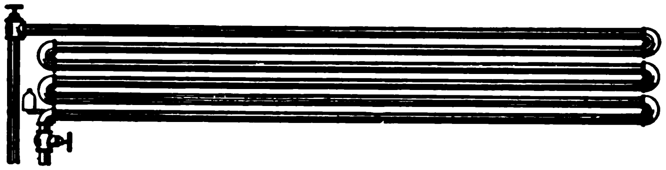


Fig. 21. "Trombone" Coil. Used where Entire Coil must be Placed on One Side of Room

When steam is first turned on a coil, it usually passes through a portion of the pipes first and heats them while the others remain cold and full of air. Therefore the coil must always be made up in such a way that each pipe shall have a certain amount of spring and may expand independently without bringing undue strains upon the others. Circulation coils should incline about 1 inch in 20 feet toward the

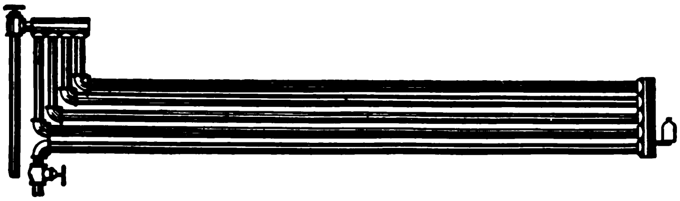


Fig. 22. "Miter" Coil. Adapted, like the "Trombone," Only to a Single Wall. Frequently Used in Factories and Shops.

return end in order to secure proper drainage and quietness of operation.

Efficiency of Radiators. The efficiency of a radiator—that is, the B. T. U. which it gives off per square foot of surface per hour—depends upon the difference in temperature between the steam in the radiator and the surrounding air, the velocity of the air over the radiator, and the quality of the surface, whether smooth or rough. In ordinary low-pressure heating, the first condition is practically constant; but the second varies somewhat with the pattern of the radiator. An open design which allows the air to circulate freely over the radiating surfaces, is more efficient than a closed pattern, and for this reason a pipe coil is more efficient than a radiator.

In a large number of tests of cast-iron and pipe radiators, working under usual conditions, the heat given off per square foot of surface per hour for each degree difference in temperature between the steam and surrounding air was found to average about 1.7 B. T. U. The temperature of steam at 3 pounds' pressure is 220 degrees, and 220—70 = 150, which may be taken as the average difference between the temperature of the steam and the air of the room, in ordinary low-pressure work. Taking the above results, we have 150 × 1.7 = 255 B. T. U. as the efficiency of an average cast-iron or pipe radiator. This, for convenient use, may be taken as 250. A circulation coil made up of pipes from 1 to 2 inches in diameter, will easily give off 300 B. T. U. under the same conditions; and a cast-iron wall radiator with ample space back of it should have an efficiency equal to that of a wall coil. While overhead coils have a higher efficiency than cast-iron radiators, their position near the ceiling reduces their effectiveness, so that in practice the efficiency should not be taken over 250 B. T. U. per hour at the most. Tabulating the above we have:

TABLE XIII

Efficiency of Radiators, Coils, etc.

TYPE OF RADIATING SURFACE	RADIATION PER SQUARE FOOT OF SURFACE PER HOUR
Cast-Iron Sectional and Pipe Radiators	250 B. T. U.
Wall Radiators	300 "
Ceiling Coils	200 to 250 "
Wall Coils	300 "

If the radiator is for warming a room which is to be kept at a temperature above or below 70 degrees, or if the steam pressure is greater than 3 pounds, the radiating surface may be changed in the same proportion as the difference in temperature between the steam and the air.

For example, if a room is to be kept at a temperature of 60°, the efficiency of the radiator becomes $\frac{160}{150} \times 250 = 267$; that is, the efficiency varies directly as the difference in temperature between the steam and the air of the room. It is not customary to consider this unless the steam pressure should be raised to 10 or 15 pounds or the temperature of the rooms changed 15 or 20 degrees from the normal.

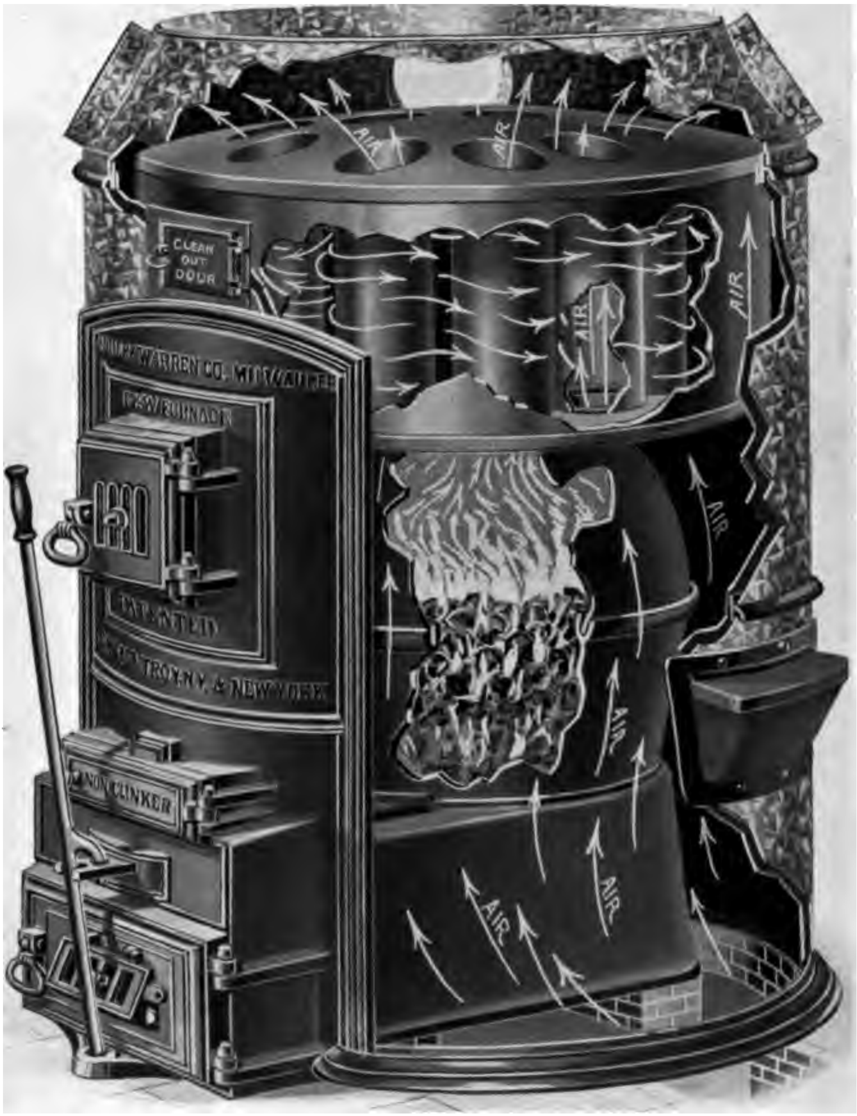
From the above it is easy to compute the size of radiator for any given room. First compute the heat loss per hour by conduction and leakage in the coldest weather; then divide the result by the efficiency of the type of radiator to be used. It is customary to make the radiators of such size that they will warm the rooms to 70 degrees in the coldest weather. As the low-temperature limit varies a good deal in different localities, even in the same State, the lowest temperature for which we wish to provide must be settled upon before any calculations are made. In New England and through the Middle and Western States, it is usual to figure on warming a building to 70 degrees when the outside temperature is from zero to 10 degrees below.

The different makers of radiators publish in their catalogues, tables giving the square feet of heating surface for different styles and heights, and these can be used in determining the number of sections required for all special cases.

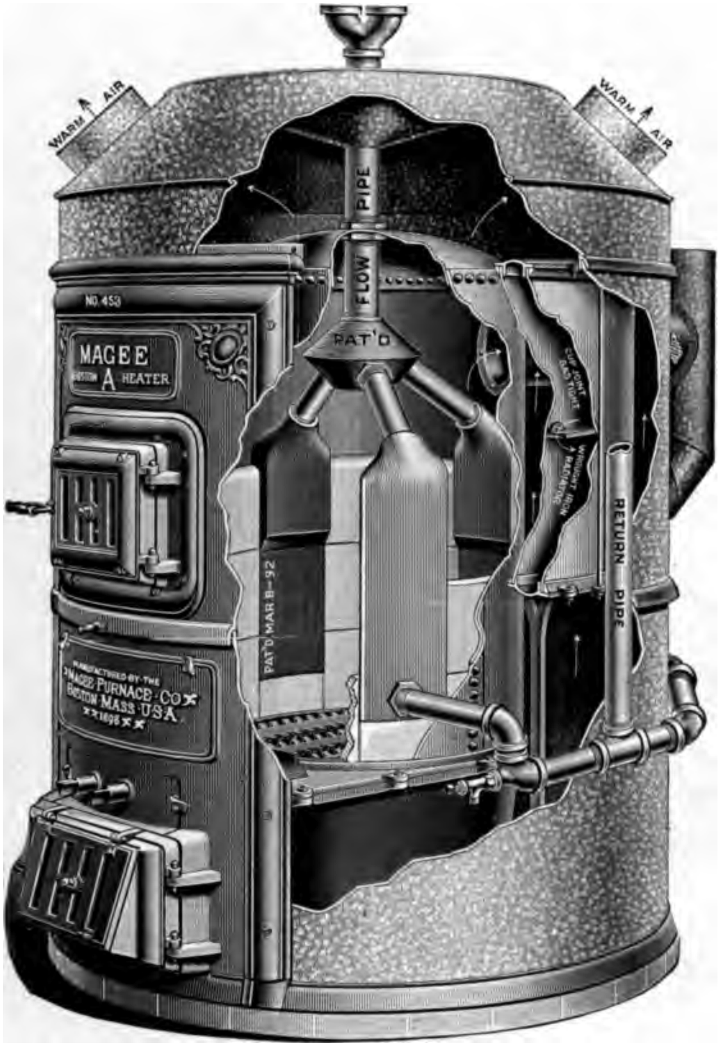
If pipe coils are to be used, it becomes necessary to reduce square feet of heating surface to linear feet of pipe; this can be done by means of the factors given below.

$$\text{Square feet of heating surface} \times \begin{cases} 3 & = \text{linear ft. of 1 -in. pipe} \\ 2.3 & = \text{`` \quad `` \quad } 1\tfrac{1}{4}\text{-in. \quad ``} \\ 2 & = \text{`` \quad `` \quad } 1\tfrac{1}{2}\text{-in. \quad ``} \\ 1.6 & = \text{`` \quad `` \quad 2 -in. \quad ``} \end{cases}$$

The size of radiator is made only sufficient to keep the room warm after it is once heated; and no allowance is made for *warming up*; that is, the heat given off by the radiator is just equal to that lost through walls and windows. This condition is offset in two ways—



STEWART "B" FURNACE WITH TUBULAR STEEL RADIATOR
Courtesy of Fuller-Warren Company, Milwaukee, Wisconsin



MAGEE TYPE "A" BOSTON HEATER
Courtesy of Magee Furnace Company, Boston, Massachusetts

first, when the room is cold, the difference in temperature between the steam and the air of the room is greater, and the radiator is more efficient; and *second,* the radiator is proportioned for the coldest weather, so that for a greater part of the time it is larger than necessary.

EXAMPLES FOR PRACTICE

1. The heat loss from a room is 25,000 B. T. U. per hour in the coldest weather. What size of direct radiator will be required?
Ans. 100 square feet.

2. A schoolroom is to be warmed with circulation coils of 1¼-inch pipe. The heat loss is 30,000 B. T. U. per hour. What length of pipe will be required? Ans. 230 linear feet.

Location of Radiators. Radiators should, if possible, be placed in the coldest part of the room, as under windows or near outside doors. In living rooms it is often desirable to keep the windows free, in which case the radiators may be placed at one side. Circulation coils are run along the outside walls of a room under the windows. Sometimes the position of the radiators is decided by the necessary location of the pipe risers, so that a certain amount of judgment must be used in each special case as to the best arrangement to suit all requirements.

Systems of Piping. There are three distinct systems of piping, known as the *two-pipe system,* the *one-pipe relief system,* and the *one-pipe circuit system,* with various modifications of each and combinations of the different systems.

Fig. 23 shows the arrangement of piping and radiators in the two-pipe system. The steam main leads from the top of the boiler, and the branches are carried along near the basement ceiling. Risers are taken from the supply branches, and carried up to the radiators on the different floors; and return pipes are brought down to the return mains, which should be placed near the basement floor below the water-line of the boiler. Where the building is more than two stories high, radiators in similar positions on different floors are connected with the same riser, which may run to the highest floor; and a corresponding return drop connecting with each radiator is carried down beside the riser to the basement. A system in which the main horizontal returns are below the water-line of the boiler is said to have a *wet* or *sealed* return. If the returns are overhead and above the water-line, it is called a *dry* return. Where the steam is exposed to extended surfaces of water, as in overhead returns, where the condensation partially fills the pipes, there is likely to be cracking or *water-hammer*, due to the sudden condensation of the steam as it comes in contact with the cooler water. This is especially noticeable when steam is first turned into cold pipes and radiators, and the condensation is excessive. When dry returns are used, the pipes should be large and have a good pitch toward the boiler.

In the case of sealed returns, the only contact between the steam and standing water is in the vertical returns, where the exposed surfaces are very small (being equal to the sectional area of the pipes), and trouble from water-hammer is practically done away with. Dry returns should be given an incline of at least 1 inch in 10 feet, while for wet returns 1 inch in 20 or even 40 feet is ample. The ends of all steam mains and branches should be dripped into the returns. If the return is sealed, the drip may be directly connected as shown in Fig. 24; but if it is dry, the connection should be provided with a siphon loop as indicated in Fig. 25. The loop becomes filled with water, and prevents steam from flowing directly into the return. As the

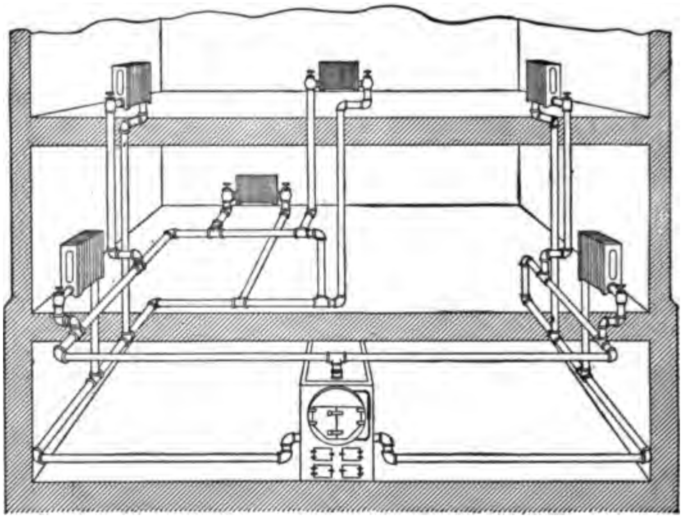


Fig. 23. Arrangement of Piping and Radiators in "Two-Pipe" System.

condensation collects in the loop, it overflows into the return pipe and is carried away. The return pipes in this case are of course filled with steam above the water; but it is steam which has passed through the radiators and their return connections, and is therefore at a slightly lower pressure; so that, if steam were admitted directly from the main, it would tend to hold back the water in more distant returns and cause surging and cracking in the pipes. Sometimes the boiler is at a lower level than the basement in which the returns are run, and it then becomes necessary to establish a *false* water-line. This is done by making connections as shown in Fig. 26.

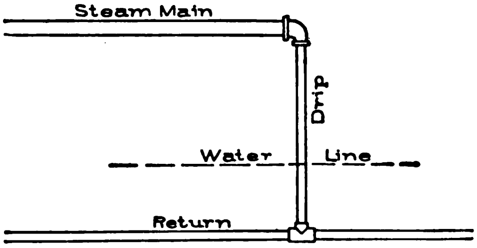


Fig. 24. Drip from Steam Main Connected Directly to Sealed Return.

It is readily seen that the return water, in order to reach the boiler, must flow through the trap, which raises the water-line or seal to the level shown by the dotted line. The balance pipe is to equalize the pressure above and below the water in the trap, and prevent siphonic action, which would tend to drain the water out of the return mains after a flow was once started.

The balance pipe, when possible, should be 15 or 20 feet in length, with a throttle-valve placed near its connection with the main. This valve should be opened just enough to allow the steam-pressure to act upon the air which occupies the space above the water in the trap; but it should not be opened sufficiently to allow the steam to enter in large volume and drive the air out. The success of this arrangement depends upon keeping a layer or cushion of cool air next to the surface of the water in the trap, and this is easily done by following the method here described.

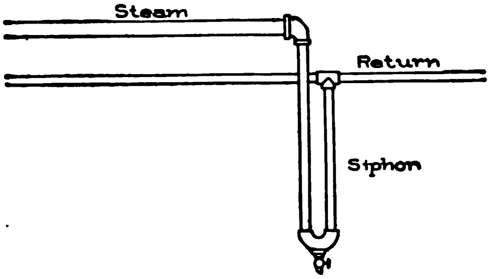


Fig. 25. Use of Siphon in Connecting Drip from Steam Main to a "Dry" Return.

One-Pipe Relief System. In this system of piping, the radiators have but a single connection, the steam flowing in and the condensation draining out through the same pipe. Fig. 27 shows the method of running the pipes for this system. The steam main, as before, leads from the top of the boiler, and is carried to as high a point as the basement ceiling will allow; it then slopes downward with a grade of about 1 inch in 10 feet, and makes a circuit of the building or a portion of it.

Risers are taken from the top and carried to the radiators above, as in the two-pipe system; but in this case, the condensation flows back through the same pipe, and drains into the return main near the floor through drip connections which are made at frequent intervals. In a two-story building, the bottom of each riser to the second floor is dripped; and in larger buildings, it is customary to drip each riser that has more than one radiator connected with it. If the radiators are large and at a considerable distance from the next riser, it is better to make a drip connection for each radiator. When the return main is overhead, the risers should be dripped through siphon loops; but the ends of the branches should make direct connection with the returns. This is the reverse of the two-pipe system. In this case the lowest pressure is at the ends of the mains, so that steam introduced into the returns at these points will cause no trouble in the pipes connecting between these and the boiler.

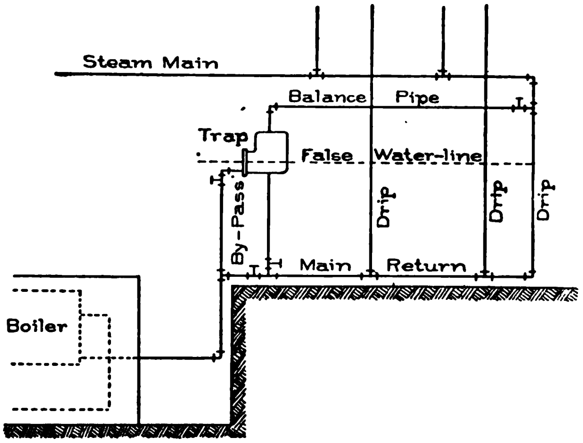


Fig. 26. Connections Made to Establish "False" Water-Line when Boiler is below Basement Level.

If no steam is allowed to enter the returns, a vacuum will be formed, and there will be no pressure to force the water back to the boiler. A check-valve should always be placed in the main return

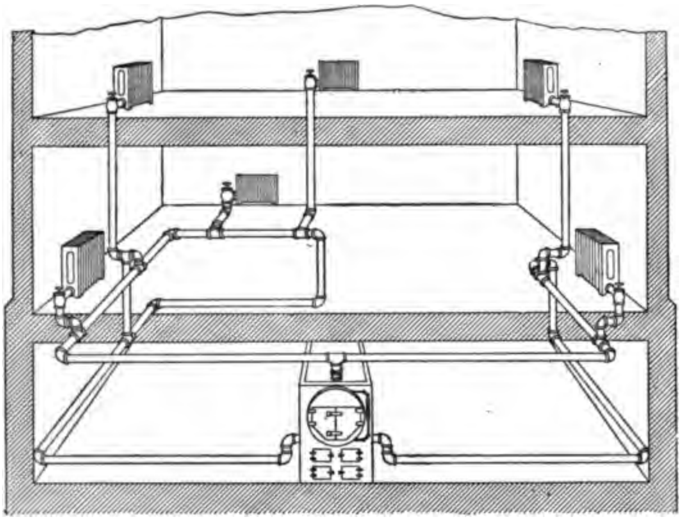


Fig. 27. Arrangement of Piping and Radiators in "One-Pipe Relief" System.

near the boiler, to prevent the water from flowing out in case of a vacuum being formed suddenly in the pipes.

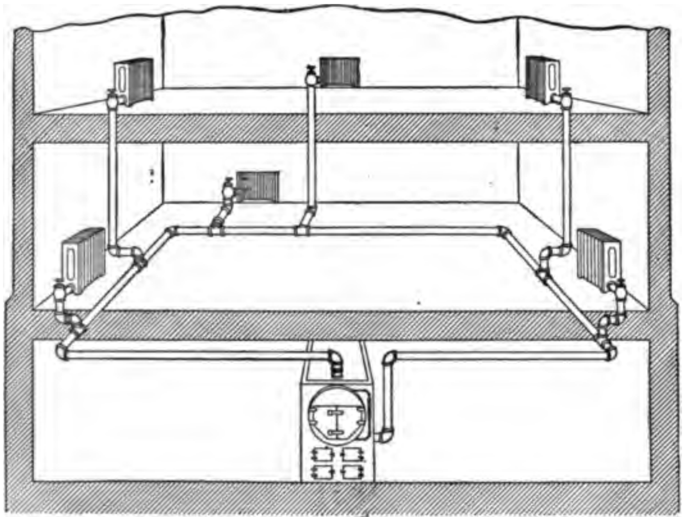


Fig. 28. Arrangement of Piping and Radiators in "One-Pipe Circuit" System.

There is but little difference in the cost of the two systems, as larger pipes and valves are required for the single-pipe method

With radiators of medium size and properly proportioned connections, the single-pipe system in preferable, there being but one valve to operate and only one-half the number of risers passing through the lower rooms.

One-Pipe Circuit System. In this case, illustrated in Fig. 28, the steam main rises to the highest point of the basement, as before; and then, with a considerable pitch, makes an entire circuit of the building, and again connects with the boiler below the water-line. Single risers are taken from the top; and the condensation drains back through the same pipes, and is carried along with the flow of steam to the extreme end of the main, where it is returned to the boiler. The main is made large, and of the same size throughout its entire length. It must be given a good pitch to insure satisfactory results.

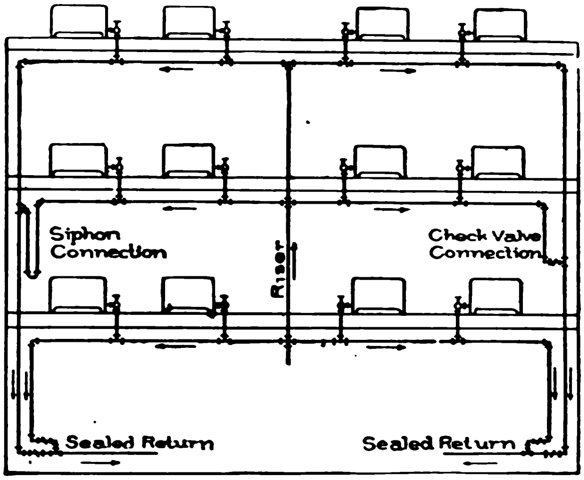


Fig. 29. "One-Pipe Circuit" System. Adapted to a Large Building.

One objection to a single-pipe system is that the steam and return water are flowing in opposite directions, and the risers must be made of extra large size to prevent any interference. This is overcome in large buildings by carrying a single riser to the attic, large enough to supply the entire building; then branching and running "drops" to the basement. In this system the flow of steam is downward, as well as that of water. This method of piping may be used with good results in two-pipe systems as well. Care must always be taken that no pockets or low points occur in any of the lines of pipe; but if for any reason they cannot be avoided, they should be carefully drained.

A modification of this system, adapting it to large buildings, is shown in diagram in Fig. 29. The riser shown in this case is one of several, the number depending upon the size of the building; and may be supplied at either bottom or top as most desirable. If steam is supplied at the bottom of the riser, as shown in the cut, all of the drip connections with the return drop, except the upper one, should be sealed with either a siphon loop or a check-valve, to prevent the steam from short-circuiting and holding back the condensation in the returns above. If an overhead supply is used, the arrangement should be the reverse; that is, all return connections should be sealed except the lowest.

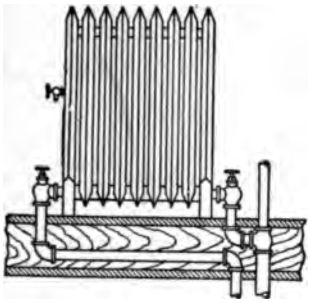


Fig. 30. "Two-Pipe" Connection of Radiator to Riser and Return.

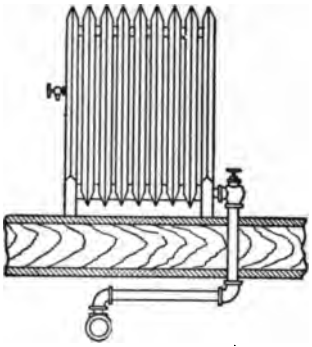


Fig. 31. "One-Pipe" Connection of Radiator to Basement Main.

Sometimes a separate drip is carried down from each set of radiators, as shown on the lower story, being connected with the main return below the water-line of the boiler. In case this is done, it is well to provide a check-valve in each drip below the water-line.

In buildings of any considerable size, it is well to divide the piping system into sections by means of valves placed in the corresponding supply and return branches. These are for use in case of a break in any part of the system, so that it will be necessary to shut off only a small part of the heating system during repairs. In tall buildings, it is customary to place valves at the top and bottom of each riser, for the same purpose.

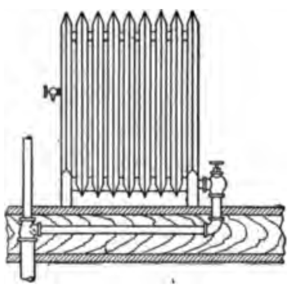


Fig. 32. "One-Pipe" Connection of Radiator to Riser.

Radiator Connections. Figs. 30, 31, and 32 show the common methods of making connections between supply pipes and radiators. Fig. 30 shows a two-pipe connection with a riser; the return is carried down to the main below. Fig. 31 shows a single-pipe connection with a basement main; and Fig. 32, a single connection with a riser.

Care must always be taken to make the horizontal part of the piping between the radiator and riser as short as possible, and to give it a good pitch toward the riser. There are various ways of making these connections, especially suited to different conditions; but the examples given serve to show the general principle to be followed.

Figs. 20, 21, and 22 show the common methods of making steam and return connections with circulation coils. The position of the air-valve is shown in each case.

Expansion of Pipes. Cold steam pipes expand approximately 1 inch in each 100 feet in length when low-pressure steam is turned into them; so that, in laying out a system of piping, we must arrange it in such a manner that there will be sufficient "spring" or "give" to the pipes to prevent injurious strains. This is done by means of offsets and bends. In the case of larger pipes this simple method will not be sufficient, and swivel or slip joints must be used to take up the expansion.

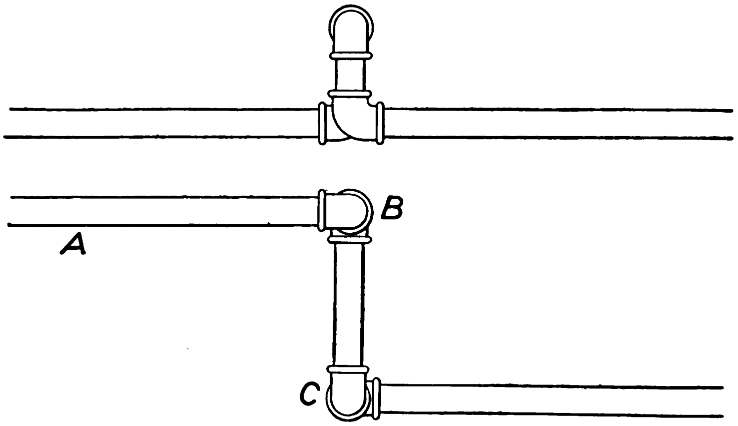


Fig. 33. Elevation and Plan of Swivel-Joint to Counteract Effects of Expansion and Contraction in Pipes.

The method of making up a swivel-joint is shown in Fig. 33. Any lengthening of the pipe *A* will be taken up by slight turning or swivel movements at the points *B* and *C*. A slip-joint is shown in

Fig. 34. The part *c* slides inside the shell *d*, and is made steam-tight by a stuffing-box, as shown. The pipes are connected at the flanges *A* and *B*.

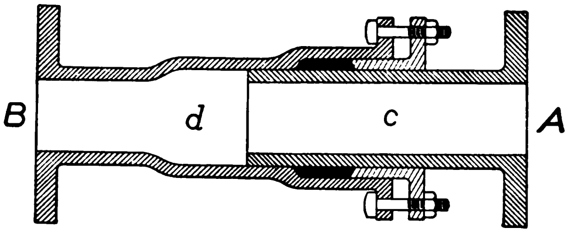


Fig. 34. "Slip-Joint" Connection to Take Care of Expansion and Contraction of Pipes.

When pipes pass through floors or partitions, the woodwork should be protected by galvanized-iron sleeves having a diameter from $\frac{3}{4}$ to 1 inch greater than the pipe. Fig. 35 shows a form of adjustable floor-sleeve which may be lengthened or shortened to conform to the thickness of floor or partition. If plain sleeves are used, a plate should be placed around the pipe where it passes through the floor or partition. These are made in two parts so that they may be put in place after the pipe is hung. A plate of this kind is shown in Fig. 36.

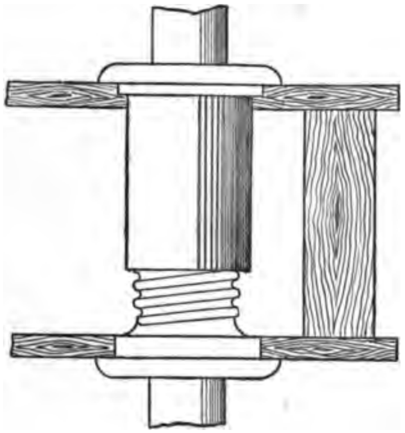


Fig. 35. Adjustable Metal Sleeve for Carrying Pipe through Floor or Partition.

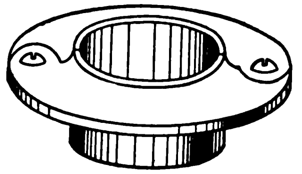


Fig. 36. Floor-Plate Adjusted to Plain Sleeve for Carrying Pipe through Floor or Partition.

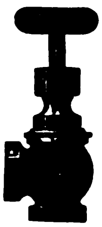


Fig. 37. Angle Valve.

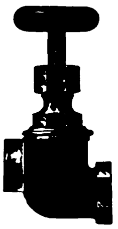


Fig. 38. Offset Valve.

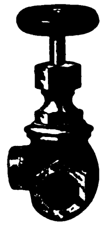


Fig. 39. Corner Valve.

Valves for Radiator Connections.

Valves. The different styles commonly used for radiator connections are shown in Figs. 37, 38, and 39, and are known as *angle*, *offset*, and *corner* valves, respectively. The first is used when the radiator is at the top of a riser or when the connections are like those shown in Figs. 30, 31, and 32; the second is used when the connection between the riser and radiator is above the floor; and the third, when the radiator has to be set close in the corner of a room and there is not space for the usual connection.

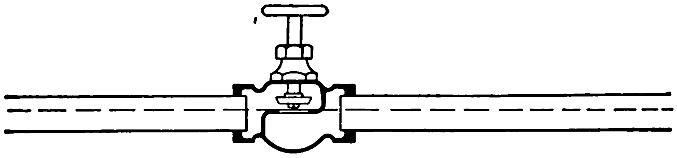


Fig. 40. Indicating Effect of Using Globe Valve on Horizontal Steam Supply Pipe or Dry Return.

A *globe* valve should never be used in a horizontal steam supply or dry return. The reason for this is plainly shown in Fig. 40. In order for water to flow through the valve, it must rise to a height shown by the dotted line, which would half fill the pipes, and cause serious trouble from water-hammer. The gate valve shown in Fig. 41 does not have this undesirable feature, as the opening is on a level with the bottom of the pipe.

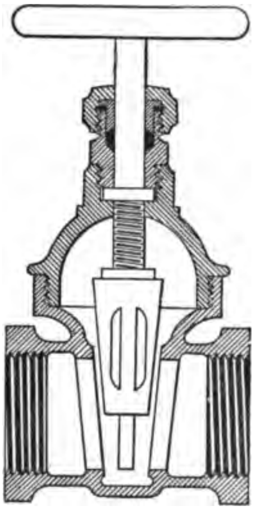


Fig. 41. Gate Valve.

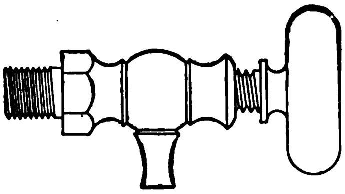


Fig. 42. Simplest Form of Air-Valve. Operated by Hand.

Air-Valves. Valves of various kinds are used for freeing the radiators from air when steam is turned on. Fig. 42 shows the simplest form, which is operated by hand. Fig. 43 is a type of automatic valve, consisting of a shell, which is attached to the radiator. *B* is a small opening which may be closed by the spindle *C*, which is provided with a conical end. *D* is a strip composed of a layer of iron or steel and one of brass soldered or brazed together. The action of the valve is as follows: when the radiator is cold and filled with air the valve stands as shown in the cut. When steam is turned on, the air is driven out through the opening *B*. As soon as this is expelled and steam strikes the strip *D*, the two prongs spring apart owing to the unequal expansion of the two metals due to the heat of the steam. This raises the spindle *C*, and closes the opening so that no steam can escape. If air should collect in the valve, and the metal strip become cool, it would contract, and the spindle would drop and allow the air to escape through *B* as before. *E* is an adjusting nut. *F* is a float attached to the spindle, and is supposed, in case of a sudden rush of water with the air, to rise and close the opening; this action, however, is somewhat uncertain, especially if the pressure of water continues for some time.

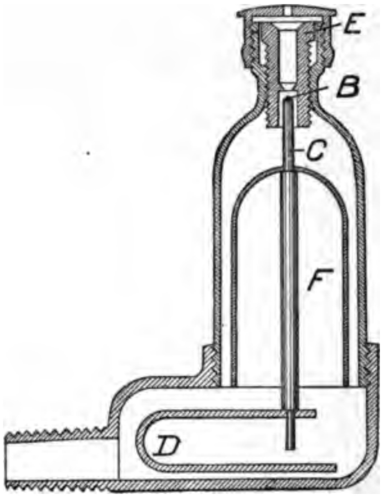


Fig. 43. Radiator Automatic Air-Valve. Operated by Metal Strip *D*, Consisting of Two Pieces of Metal of Unequal Expansive Power.

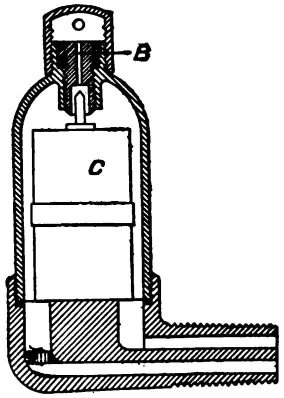


Fig. 45. Automatic Air-Valve Operated by Expansion of Drum *C* Due to Vaporization of Alcohol with which it is Partly Filled.

There are other types of valves acting on the same principle. The valve shown in Fig. 44 is closed by the expansion of a piece of vulcanite instead of a metal strip, and has no water float.

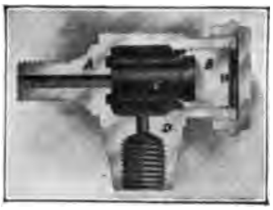


Fig. 44. Section of Jenkins Improved Automatic Air-Valve.

The valve shown in Fig. 45 acts on a somewhat different principle. The float C is made of thin brass, closed at top and bottom, and is partially filled with wood alcohol. When steam strikes the float, the alcohol is vaporized, and creates a pressure sufficient to bulge out the ends slightly, which raises the spindle and closes the opening B.

Fig. 46 shows a form of so-called *vacuum valve.* It acts in a similar manner to those already described, but has in addition a ball check which prevents the air from being drawn into the radiator, should the steam go down and a vacuum be formed. If a partial vacuum exists in the boiler and radiators, the boiling point, and consequently the temperature of the steam, are lowered, and less heat is given off by the radiators. This method of operating a heating plant is sometimes advocated for spring and fall, when little heat is required, and when steam under pressure would overheat the rooms.

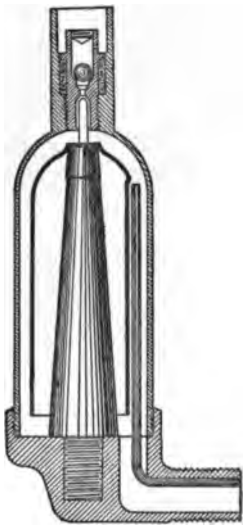


Fig. 46. Vacuum Valve.

Pipe Sizes. The proportioning of the steam pipes in a heating plant is of the greatest importance, and should be carefully worked out by methods which experience has proved to be correct. There are several ways of doing this; but for ordinary conditions, Tables XIV, XV, and XVI have given excellent results in actual practice. They have been computed from what is known as D'Arcy's formula, with suitable corrections made for actual working conditions. As the computations are somewhat complicated, only the results will be given here, with full directions for their proper use.

Table XIV gives the flow of steam in pounds per minute for pipes of different diameters and with varying drops in pressure between the supply and discharge ends of the pipe. These quantities are for pipes 100 feet in length; for other lengths the results must be corrected by the factors given in Table XVI. As the length of pipe increases, friction becomes greater, and the quantity of steam discharged in a given time is diminished.

Table XIV is computed on the assumption that the drop in

TABLE XIV

Flow of Steam in Pipes of Various Sizes, with Various Drops in Pressure between Supply and Discharge Ends

Calculated for 100-Foot Lengths of Pipe

DIAM. OF PIPE	DROP IN PRESSURE (POUNDS)								
	¼	½	¾	1	1½	2	3	4	5
1	.44	.63	.78	91	1.13	1.31	1.66	1.97	2.26
1¼	.81	1.16	1.43	1.66	2.05	2.39	3.02	3.59	4.12
1½	1.06	1.89	2.34	2.71	3.36	3.92	4.94	5.88	6.75
2	2.93	4.17	5.16	5.99	7.43	8.65	10.9	13.0	14.9
2½	5.29	7.52	9.32	10.8	13.4	15.6	19.7	23.4	26.9
3	8.61	12.3	15.2	17.6	21.8	25.4	32	31.8	43.7
3½	12.9	18.3	22.6	26.3	32.5	37.9	47.8	56.9	65.3
4	18.1	25.7	31.8	36.9	45.8	53.3	67.2	80.1	91.9
5	32.2	45.7	56.6	65.7	81.3	94.7	120	142	163
6	51.7	73.3	90.9	106	131	152	192	229	262
7	76.7	109	135	157	194	226	285	339	390
8	108	154	190	222	274	319	402	478	549
9	147	209	258	299	371	432	545	649	745
10	192	273	339	393	487	567	715	852	977
12	305	434	537	623	771	899	1,130	1,350	1,550
15	535	761	942	1,090	1,350	1,580	1,990	2,370	2,720

pressure between the two ends of the pipe equals the initial pressure. If the drop in pressure is less than the initial pressure, the actual discharge will be slightly greater than the quantities given in the table; but this difference will be small for pressures up to 5 pounds, and may be neglected, as it is on the side of safety. For higher initial pressures, Table XV has been prepared. This is to be used in connection with Table XIV as follows: First find from Table XIV the quantity of steam which will be discharged through the given diameter of pipe

TABLE XV

Factors for Calculating Flow of Steam in Pipes under Initial Pressures above Five Pounds

To be used in connection with Table XIV

DROP IN PRESSURE IN POUNDS	INITIAL PRESSURE (POUNDS)					
	10	20	30	40	60	80
¼	1.27	1.49	1.68	1.84	2.13	2.38
½	1.26	1.48	1.66	1.83	2.11	2.36
1	1.24	1.46	1.64	1.80	2.08	2.32
2	1.21	1.41	1.59	1.75	2.02	2.26
3	1.17	1.37	1.55	1.70	1.97	2.20
4	1.14	1.34	1.51	1.66	1.92	2.14
5	1.12	1.31	1.47	1.62	1.87	2.09

tion in connection with the open-tank system, the radiators must be deeper than for steam heating, in order properly to heat the air.

The greater depth retards the flow of air; and since the water is at a much lower temperature than steam, the heating capacity of indirect extended-surface hot-water radiators should be taken at not far from 300 heat units per square foot per hour, as against 400 or more heat units for indirect steam radiation.

To compute the amount of radiation required, proceed as explained for indirect steam heating; that is, compute the amount of direct radiation as pointed out under the preceding heading, then add not less than 60 per cent to this amount, to ascertain the indirect radiating surface required.

This method, though perhaps crude, has the advantages of being simple and of affording a check on the work, since one soon knows by experience about what the ratio should be to heat a room of given size by direct radiation. For example, take a room with 3000 cubic feet, to heat which the ratio for direct radiation should be, say, 1 square foot to 30 cubic feet, giving a 100-square foot radiator. Adding 60 per cent for indirect radiation, gives 160 square feet, or a ratio of 1 square foot to a little less than 20 cubic feet of space.

Indirect hot-water radiators with extended pins or ribs will, with the open-tank system, give off not far from 250 to 300 heat units per hour per square foot of extended surface.

DUCTS AND FLUES

Areas of Ducts and Flues. When indirect radiation is installed primarily for heating, ventilation being a secondary consideration, it is desirable to make the flues somewhat smaller in proportion to the heating surface than is done with steam heating. If the flues are made too large, the flow through the radiators will be too rapid, and the air will not get hot enough. It costs far more in fuel to heat with a large volume of moderately warmed air than with a smaller volume of hotter air.

Duct and flue proportions for hot-water heating should be approximately as follows:—Cold-air ducts, ¾ to 1 sq. in. per sq. ft. of indirect radiating surface; first-floor flues, 1¼ to 1½ sq. in. per sq. ft.; second-floor flues, 1 to 1¼ sq. in. per sq. ft.; third-floor flues and above, ¾ to 1 sq. in. per sq. ft. of surface.

The backs and sides of flues in exposed walls should be covered with non-conducting material.

Flue Velocities. The flue velocities will be somewhat lower than with steam heating, because of the lower temperature of the air. Reasonable allowance would be 250, 350, 400, and 450 feet per minute for the first, second, third, and fourth floors respectively.

Heating Water. The size of heater or steam coil necessary to heat water may be very readily determined on the heat-unit basis, if one knows the volume of water to be heated, the number of degrees its temperature is to be raised, and the time during which the heating must be done.

For example, what size of heater would be required to heat 300 gallons of water in 6 hours from 60° to 160°?

In one hour 50 gals. would be heated 100° F.; and since one gal. weighs 8⅓ lbs., 50 × 8⅓ × 100 = 41,667 heat units would be required.

Small heaters may be counted on to transmit to the water about 7000 heat units per pound of coal burned. The rate of combustion should be assumed to be from 3 to 6 pounds per square foot of grate per hour, according to the amount of attendance it is convenient to give.

With a 4-pound rate, 28,000 heat units would be furnished per square foot of grate surface per hour for heating the water. Therefore the heat units per hour necessary to raise the temperature of the water—*viz.*, 41,667—divided by 28,000, gives the number of square feet of grate surface required, which is equal to about 1½ corresponding to a diameter of 16½ inches.

To determine the size of steam boiler and coil required to heat a large volume of water in a tank, proceed as follows: Take, for example, a 24,000-gallon tank, the water in which is to be heated from 45° to 75° in 10 hours. Now 24,000 gals. × 8⅓ pounds × 30° rise in temperature = 6,000,000 heat units, or 600,000 heat units per hour.

Assuming 8000 heat units to be utilized per pound of coal burned at, say, a 7½-pound rate, one square foot of grate will supply 60,000 heat units per hour; hence, 10 square feet of grate surface will be required.

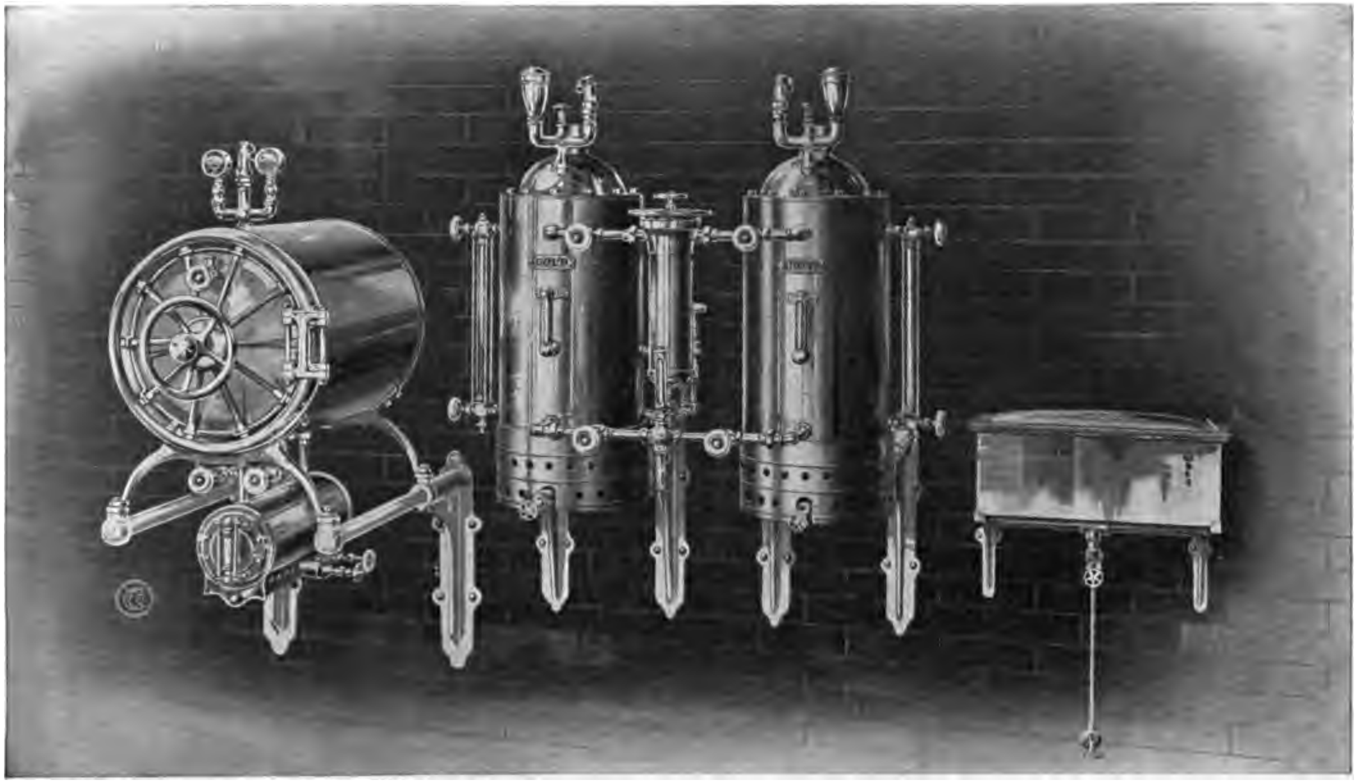
There will, however, be a certain loss of heat from the tank by radiation, conduction, and evaporation; therefore, not less than, say, 12 square feet should be used in order to provide a reasonable margin.

As to the size of steam coil required, a square foot of pipe surface surrounded by circulating water may be assumed to transmit to the water not far from 100 heat units per degree difference in temperature between the steam and the water in contact with the pipe.

Assume the steam temperature to be 230°, corresponding to a trifle more than 5 pounds gauge pressure. When the water in the tank is cold, the condensation of steam in the coil will be much more rapid than when the surrounding water becomes warmer. The average temperature of the water during the 10-hour period is 60°; but the water leaving the pipe and in contact with the upper half of its surface is at a considerably higher temperature than the main body of water in the tank; therefore, with natural circulation, it is well to make ample allowance for the effect of this skin of warm water surrounding the steam coils, and to assume that they will not give off more than $\frac{2}{3}$ as much heat as that corresponding to the difference in temperature between the steam and the water in the tank, based on 100 heat units per degree difference as stated above.

In other words, allow only 66$\frac{2}{3}$—or, in round numbers, 70—heat units per hour per degree difference in temperature between the steam and the water in the tank.

If the difference in temperature is $230° - 70° = 160°$, on the basis stated, one square foot of coil would give off $70 \times 160 = 11,200$ heat units per square foot per hour; and since 600,000 heat units must be supplied to the water, a 53-square foot coil or slightly larger would be required, equal to about 122 ft. of 1$\frac{1}{4}$-inch pipe.



BATTERY OF HIGH-PRESSURE STAIR RISERS MOUNTED ON WALL BRACKETS

Courtesy of Crane and Nordway Company, Chicago

PLUMBING

PART I

Plumbing occupies an important position among the trades as an application of Sanitary Science.

Sanitary science is defined by an eminent authority* as "that body of hygienic knowledge, which, having been sufficiently and critically examined, has been found so far as tested to be invariably true. Its phenomena are natural phenomena; its laws are natural laws; its principles are scientific principles."

The same authority defines the sanitary arts as "those methods and processes by which the applications of the principles of sanitary science are effected," and would include plumbing with other practical arts of construction involved in sanitary engineering and architecture.

Having thus noted the position occupied in this broad field by the matters under consideration, we may define plumbing as *the art of placing in buildings the pipes and other apparatus used for introducing the water supply and removing the foul wastes.*

Historically, the plumber is primarily one who works in lead; but this definition would be a misnomer applied to the handicraftsman of to-day. While in time past, and even within the memory and practice of men now working at the trade, it suited the occupation designated as *plumbing,* the term "plumber" survives the transition from lead to iron more by reason of established usage than from its fitness to indicate the workman of the present.

Two score of years ago, traps and soil, waste, and supply pipes were in many localities almost wholly of lead; and much of the larger pipe was hand-made. Lead was then everywhere more frequently used for all these purposes than it is anywhere in the country now. To-day, first-class plumbing is possible in any type of building without employing a vestige of lead, and that, too, with fixtures and fittings regularly on the market. Lead, however, is still used to a marked extent in plumbing, principally for traps, pipe connections, calked joints, water-service pipes, tank linings, flashings, etc. Its retention for these secondary purposes is due generally to superior fitness; yet in some instances it is because of the style of connection provided on certain fixtures, or for other reasons independent of the merits of the metal. On the whole, its loss of prestige has been slow and impartial. Indeed, those manually skilled in the manipulation of lead have often opposed the adoption of other materials sufficiently to retard substitution of the better material.

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* *The Principles of Sanitary Science,* by Wm. T. Sedgwick.

Lead has unequaled merit for plumbers' use in specific instances; and if the trade has suffered by injudicious substitution of other material during its rapid evolution in recent years, time will adjust the error as the fitness of lead becomes apparent. For service lines in the ground, no other material lasts longer or gives more satisfaction than lead, provided the use of lead is safe with the particular water which flows through it. For cold-water lines inside buildings, it answers well. Wood tanks properly lined with lead are, in many cases, the best for indoor storage.

Lead pipe is not self-supporting in any position, in the sense that iron or brass may be considered so; and the providing of reasonably permanent support for lead work is an expensive item. Lead pipe costs more than iron or brass, in every case; and the cost increases proportionately with the extra weight necessary for all but very light pressures. Furthermore, the ordinary merchant's iron pipe, or seamless brass pipe of iron-pipe size and thickness, will withstand the pressure used on any municipal or private water supply in America.

Lead does not serve well for hot water. The contraction while cooling appears not to equal the expansion from heating; hence the pipe deteriorates at the hottest points, usually showing weakness first near the reservoir in the kitchen, especially at bends, and finally crystallizing beyond repair at those points. So much trouble has been experienced with stove and range connections of lead, that lead pipe for this purpose has been entirely abandoned, though lead connections have prevented disastrous water-back explosions by melting from heat conducted, while the remainder of pipe and storage tank were yet frozen. The sensible adoption of iron and brass for hot water has led to the use of these metals in both hot and cold service lines.

With reference to the action of frost, lead pipe has an advantage in that the diametrical expansion of the water when freezing does not burst the pipe at the point frozen, unless it has been repeatedly swelled from the same cause. Lateral extension of the core of ice in the portion frozen, crowds the water which it cannot compress; and, as the ice is frozen to the wall of the pipe, the weakest place ruptures. Sometimes a faucet ball will be driven in, and occasionally a coupling collar will be stripped of its threads; but usually room is made for the extra volume of the water by the pipe swelling to an egg-shape and bursting at one point. Such a break can be repaired by wiping a single patch or joint on the original pipe.

Frost breaks in lead pipe nearly always occur on the house side of the point frozen, because the water in the street end is easily driven toward the main. Air-chambers on the house service would and do often obviate the bursting of lead pipe; but where the type of faucets or a limited pressure does not require their use in order to prevent reaction, plumbers frequently omit them, under the impression that air-chambers can serve no other good purpose.

With iron pipe, frost breaks are more serious. Diametrical expansion splits the pipe at the point frozen every time freezing occurs; and lateral extension of the ice staves in the faucet stems, etc., quite or more frequently than would happen with lead pipe under the same conditions. Of late years, the improvement in types of buildings, more careful provision against frost on the part of plumbers, and the vigilance of the Weather Bureau in giving warning of approaching cold snaps, have made insignificant the amount of damage by frost in both kinds of pipe.

Lead pipe, as a rule, requires less trench work on ground lines than iron pipe, because drilling, even if very poorly aligned, will often suffice to get the pipe in place. There are numerous instances, however, where longer stretches of iron pipe have been placed in drilled holes than would be practicable with lead at the same excavating cost. It is well to remember that any small line of house service in the ground should be placed deeper, so far as immunity from frost alone is concerned, than is necessary for the protection of large pipes in the same locality, because the volume of contents in house pipes is small, the wall surface of the pipe relatively large, and the flow of the water not so regularly maintained.

The action of natural waters on lead has been a matter of wide discussion by able men. The subject of possible contamination of water supply through the agency of lead conduits, is too broad, however, for full consideration here, and will therefore be but briefly touched upon. This trait of lead has been voiced against its use, with more or less effect; but known cases of poisoning from this source have been exceedingly rare. Galvanized-iron pipe charges the water with salts of zinc when the water contains certain impurities; and most other kinds of pipe are also more or less open to objection at times by reason of their injurious effect on the water, the staining of fixtures, etc. Some of the salts of lead formed by the agency of water conveyed through lead supply pipe, are protective. Others, without doubt—fortunately of rare occurrence in actual practice—are corrosive. Sulphate or phosphate of lime, in solution, will part with its acid in passing through lead pipe, the acid combining with a new base (lead) and forming sulphate or phosphate of lead as the case may be. Chloride, sulphate, nitrate, borate, and other compounds of lead, may be similarly formed. These incrust the pipe; and such of them as are practically insoluble in water protect the lead from further attack, thus preserving the quality of the water. Carbonate, sulphate, and phosphate of lead, which doubtless form most frequently in lead water pipes, belong to the protective class. Of course, not all the compounds mentioned are encountered in any one source of supply. Chemical compounds designed to produce an insoluble incrustation have sometimes been purposely placed in solution, and allowed to stand in systems of lead supply pipe where it was known that the water to be commonly used would otherwise be dangerously corrosive. In view of the possibility of such precautionary measures, the deleterious effect of lead on many water supplies, and the consequent menace to health if lead were used indiscriminately, could hardly alone to any appreciable extent result in the substitution of pipe of other material.

Lead has been thus dwelt upon at the outset, because the industry of plumbing itself derived its name from this metal (*Plumbum,* Latin for "lead"). A discussion sufficient to define broadly the present and past status of the metal in the plumbing business, is certainly apropos in this connection. To many persons, the term "Plumbing" suggests lead and lead work generally, without regard to its distinctive forms, some of which are quite foreign to the ordinary trade meaning. To those acquainted with the building practices of Europe, visions of lead-covered roofs and spires, rainwater heads, etc., in addition to manifold other uses of the metal not common in America, may come to view in the mind's eye when "plumbing" is mentioned. To American plumbers of the past generation, "plumbing" suggested stacks of hand-made lead soil and waste pipe; hand-made lead traps; lead "safe" pans cumbersomely boxed-in under fixtures; ridiculously small lead ventilation pipes; lead drip-trays; lead supply pipes (sometimes also hand-made); all "wiped" joints and seams; and blocks, flanges, braces, boards, and boxes galore, jutting out in profusion, for supports, covering, etc.

In reality, we in America have now but little of what the name "plumbing" would lead the uninitiated to expect. Stacks of plain or galvanized wrought-iron pipe, or of plain, tarred, or galvanized cast-iron pipe, of weight to suit the height of building and to serve as main soil, waste, and ventilation pipes, with sundry lead bends and ends for fixture connections—these, with galvanized wrought-iron or brass pipes for supply, constitute the "roughing-in" stage of a job of plumbing; while painted or bronzed main lines exposed to view, galvanized-iron and nickel-plated brass pipe, with fixtures, partitions, etc., make up a view of the finished work, conveying little idea of the functions and importance of the unseen portions. Finished work in an unpretentious dwelling or storehouse, when properly charted, is fairly easy for even the house-man to understand. In large apartment and office buildings, department stores, etc., however, the plumbing, ventilating, gasfitting, heating, and automatic sprinkler pipes and electric conduits, make, in any but the finished state, a maze of pipe beyond the understanding of any except engineers well versed in those lines of work. In the completed work, the details are concealed. The toilet rooms present an orderly perspective of closets, lavatories, or other fixtures, as the case may be, with simple connections according with the customary finish, kind, or purpose of the pipe.

This apparent harmony, proportion, and simplicity in the result, coupled with a memory of sundry glimpses of a confusion of pipes in the rough state, has, it is to be regretted, propagated in many minds, a sense of false security regarding plumbing, based on the assumption of the plumber's evident ability to produce order and perfect service out of what in the "roughing-in" stage looked chaotic to a hopeless degree. The bulk of plumbing work, however, is not of the "skyscraper" class, nor is it handled by the same type of skill and superintendence. Any feeling of confidence or sense of security on the part of the public, is treacherous if based on the assumption that only by a degree of skill in direct proportion to the size of the job can satisfactory plumbing service be provided in residential and other small buildings. There is evidence of a somewhat indifferent state of the public mind regarding the plumber and his work, induced by the reasons stated and also by lack of due consideration and appreciation of conditions wrought by progress in other trades.

Plumbing, in its advancement, is merely keeping pace with the allied lines on which it is dependent. Their progress has created new conditions to be met; and as the future plumber will hail from the ranks of the populace, the light in which the public regards the plumber and the importance of his trade will have no uncertain bearing on the character and earnestness of those who take up the calling. The rank and file of apprentices have already too long been attracted merely on the score of a promising means of livelihood. There is ample reason to begin a plumbing career with all the pride felt by followers of any other vocation. It is altogether improbable that any individual will be found with so much education or such promising ability as to give rise to just grounds of fear that plumbing will not offer him sufficient scope to acquit himself with dignity.

The advent of tall buildings, the general increase in the height and other proportions of buildings in cities, and the changes in material and in design of fixtures, together with the abnormal demand resulting from the decreased cost, natural growth, and gradual awakening through education to the value of sanitary conveniences, have brought about a condition of affairs which the old-line plumbers were incapable of coping with, and which the old apprenticeship system was inadequate to provide men capable of dealing with in a creditable manner. The plumbing of one large building involves as much work as hundreds of the average small jobs put together. The handling of such work under the conditions that have prevailed, has developed a deplorable state of so-called "specialism." Men engaged in "roughing-in" a large job are likely to tell you with entire truthfulness that they have no idea what types of closets or other fixtures are to be used; that they know nothing of the principles or merits of plumbing fixtures, and do not need to; that they never connected a fixture in their whole career; that the finishers do that kind of work. By further inquiry one would find the "finishers" utterly at sea in the work of "roughing-in," and accordingly ignorant of the whys and wherefores that govern the success of a job as a unit. These men, called "plumbers," are exceedingly skilful and rapid within their limitations; but it is easy to infer the fate of a job intrusted to such hands alone, and in practice it has been proven that others of metropolitan practice, and merely lacking in variety of experience, were not capable of creditable results on general residence work of the ordinary class.

When the largest jobs were completed in a comparatively short time, and when much of the training which went to make up the plumber's accomplishments was credited to the manual practice necessary to master the working of lead and solder, a period of service in shop and job practice, coupled with oral instructions from the journeyman, served fairly well to make a plumber out of raw material within the period allotted by the American abridgment of the apprenticeship term. On the work of to-day, however, there would be great chances of an apprentice serving such a term without seeing anything of more than from two to five jobs. He would be lucky if it fell to his lot to get even a little experience in each of the natural divisions of those jobs; and again fortunate if those jobs happened not to have the same general layout or to employ identically the same make of fixtures, for there are many shops which seem to have the faculty of securing work from certain particular sources, and which are equally likely for one reason or another to be recommending and using, where possible, one particular make of goods to the exclusion of other kinds just as good or better. These and kindred features now met with on every hand in practice, are stumbling-blocks—prohibitive, in fact, of anyone learning the plumbing trade within any period of time that can sensibly be prescribed for the acquiring of a trade or profession.

For more than a decade, the often-avowed reluctance of journeymen to teach apprentices has been held responsible for the trend of these affairs affecting the practice of the industry; but in the light of what has been said, it is easy to determine what it was that really introduced the Plumbing Correspondence School and Plumbing Trade Classes. It was *necessity*. Trade journals have done and are still doing good work in this line; but their best efforts, added to the opportunities of practice, were insufficient. There was no other satisfactory solution than the Correspondence School—no other route to the acquisition of principles and acquaintanceship with the accumulated information as to the relative merit or fitness of certain materials, designs, systems, etc., and as to the conditions under which this or that would serve well, while it might act just the reverse under other circumstances. .

Under the present *régime,* it is not only apprentices and those who intend becoming such, but journeymen as well, that need to seek aid in the schools. The citizen at large, also, serves his own interest in informing himself in a general way at the same fountain, so as to be able to discriminate for himself in matters pertaining to plumbing. Furthermore, any real plumber would prefer that his customer should be familiar with the work in hand. Fewer misunderstandings occur when such is the case, and there is a keener appreciation of good work on one hand and a corresponding effort to merit approval on the other. There is, too, in favor of the plumber, when the customer is informed, an absence of those niggardly tactics of trying to secure much for little, of sacrificing quality and future satisfaction by reducing first cost below the safe limit. The well-informed customer never makes you feel that all plumbing is alike to him and a necessary evil to be paid for at rates far in excess of its value.

With the foregoing introduction in mind let us look further into the subject and see what "Plumbing" really is. Whether we are actual or self-nominated apprentices, journeymen, masters, or the prospective customer himself, a view of the matter will be beneficial, if only in the sense of refreshing memory.

There was a time when sanitary conveniences, crude in comparison with the present, were considered mere luxuries. Under the present views of life and the conditions of living, we may with greater propriety consider these erstwhile luxuries as actual necessities, though they are often luxurious to a degree that dwarfs into insignificance other appointments which even then were granted to be essentials. Plumbing is, therefore, neither in fact nor in opinion, a matter of simple luxury for the rich and delicate, but is, rather, an important subject of deep salutary interest on the one hand and of business acumen on the other—a matter of essentials deeply affecting the best interests of our own health and that of our neighbors, with which mere sentiment has no ground for association. The time when it was thought sufficient to fan out the mosquitoes in summer and break the ice in winter at the family rain barrel in order to wash our faces and hands, has passed. A dwelling job may now embrace almost the entire range of plumbing fixtures. There is therefore no better example from which to build a word-picture of Plumbing.

PLUMBING FIXTURES

Bathtubs. Bathtubs are a prime factor in plumbing. They are of various types:—(1) Wooden cases, with sheet-metal lining, usually copper, Fig. 1; (2) all copper, steel-clad copper, and all steel, suitably mounted, as shown in Fig. 2; (3) cast iron, enameled, with a vitreous glaze fused on the iron, as in Figs. 4 and 5; (4) solid porcelain, potters' clay properly fired, with vitreous glaze fired on, as in Fig. 3; and (5) marble, variegated or otherwise, cut from the solid block. Their cost ranges in the order mentioned, but the types shown in Figs. 1 and 2 are seldom used.

The relative merit of the different materials and types is not so easily designated. Porcelain and marble baths are large, very heavy, and imposing-looking; and therefore are often selected on the score of massiveness, with a view to harmonizing with the dimensions and finish of the house. One would suppose the mass of material in such baths would have the effect of cooling the water to an annoying extent; but careful tests have revealed no appreciable difference in the effect of thin as compared with thick bathtubs on the warmth of water, and but little in their pleasantness of touch to the person. The bath of most pleasant touch was that of indurated wood fiber, which, however, had but little success, on account of its lack of stability.

Most baths are made in from two to five regular sizes, ranging from 4 to 6 feet in extreme length. The general shapes are the *French*, Fig. 3; the *Modified French*, Fig. 4; and the *Roman*, Fig. 5. The various French patterns have the waste and supply fittings at the foot, which is modified in form to accommodate them. The waste water travels the length of the tub to reach the outlet, and generally leaves scum and sediment on the interior while emptying. Baths of the French type are suited to corner positions, or to positions in which one side runs along the wall; but the ideal position for a bathtub, in the interest of cleanliness, is with the foot end to the wall,

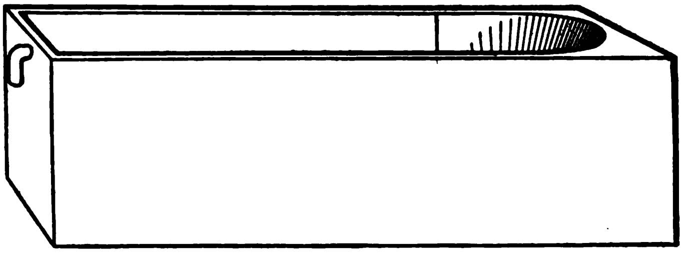


Fig. 1. Wooden Case Bathtub, with Sheet-Metal Lining.

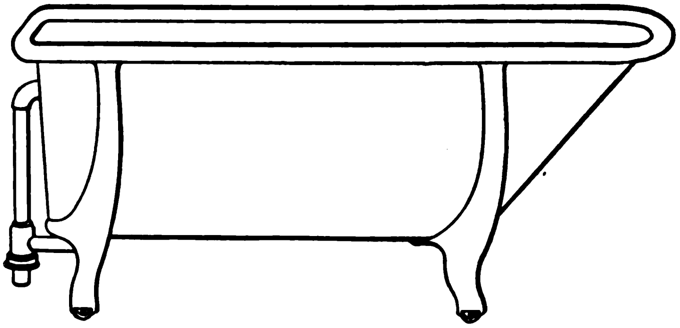


Fig. 2. All-Copper, Steel-Clad Bathtub.

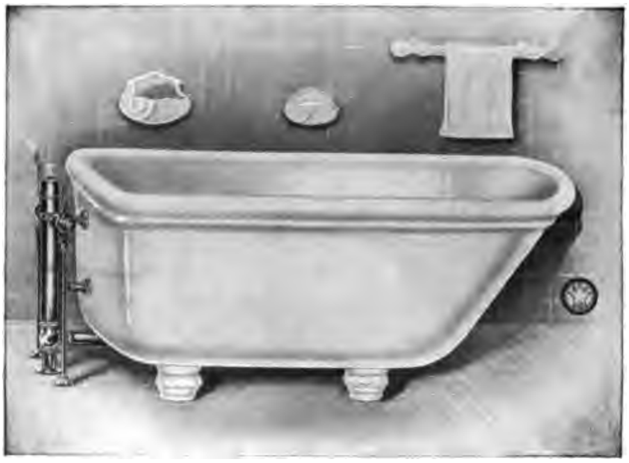


Fig. 3. Solid Porcelain Bathtub, French Pattern
Courtesy of The Trenton Potteries Company, Trenton, New Jersey

thus permitting entrance from either side. A medium size is best suited to the usual provision for supplying hot water for bath purposes; and is also preferred by many because the feet reach the foot, enabling a person, when submerging the body, to keep the head out of water, with the shoulders resting on the slant at the head of the tub.

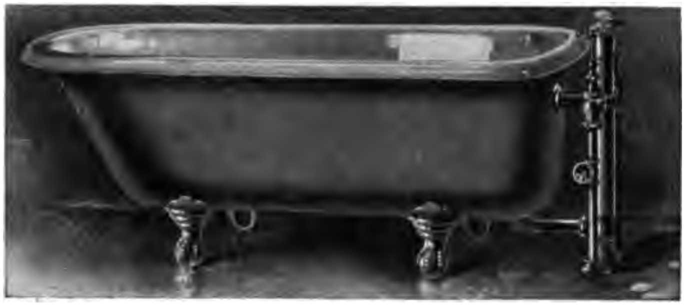


Fig. 4. Enameled-Iron Bathtub with Three-Inch Roll Rim
Courtesy of Crane Company, Chicago

The rims of baths vary from 1½ to 5 inches in width. The larger rims are easy on the person in getting in and out of the bath, and are often used in lieu of a bath seat. In iron baths with rims large enough, the fittings are sometimes passed through the rim, as illustrated in Fig. 6, thus giving them additional stability and making the stated fixture length include the whole space necessary for its installation. This style of bath fitting is shown in Fig. 7.

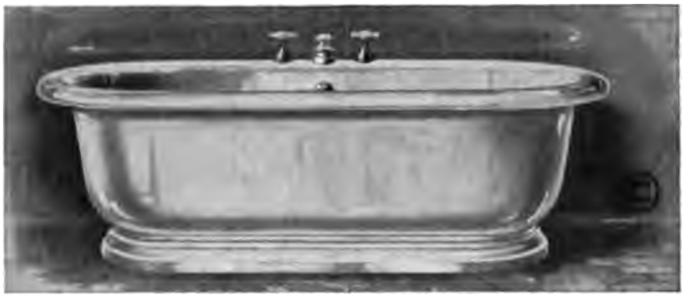


Fig. 5. Enameled-Iron Bathtub with Four-Inch Roll Rim. Fixtures Located in Center of Wall Side
Courtesy of Crane Company, Chicago

Nominal sizes of baths now include the whole length of the fixture proper. Formerly many awkward mistakes resulted from lack of uniformity, one not always knowing whether to consider the nominal size as inside measurement only or including twice the rim width. In cast tubs, actual measures vary slightly from the nominal, because of the furnace effect when heating to enamel. The variation, however, is not sufficient to be considered in noting the space required, or to require any advance in roughing-in measurements.

Roman baths have ends alike, with the fittings at the center of one side, as illustrated in Fig. 8, and the waste outlet at the center of width and length. In general, they empty with better effect, and may be placed in either right or left corner or free of all the walls; but the best position, everything considered, is with the fitting side near the wall, and not against either end of the room.

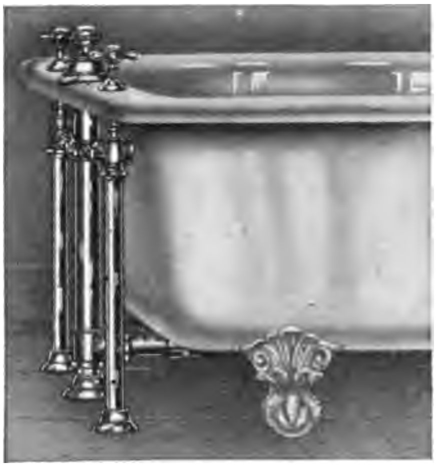


Fig. 6. Fittings Passed through Rim of Enameled Iron Bathtub to Give Additional Stability
Courtesy of Federal-Huber Company, Chicago

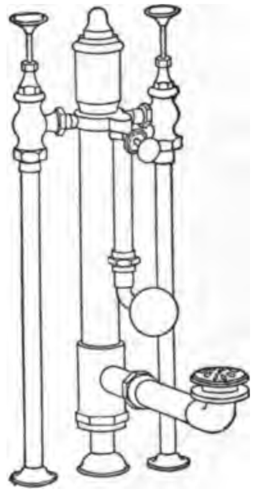


Fig. 7. Bathtub Fittings of Low-Bell Type
Courtesy of Federal-Huber Company, Chicago

Any finish for iron bathtubs, other than plain paint, should be put on at the factory; iron surfaces cannot be ground and the successive coats of paint dried on in place, properly or cheaply.

Waste fittings and the outlets of baths have always been made too small. Slow emptying takes valuable time, and results in the adherence of scum, which necessitates careful cleansing of the bath before it is used again.

The fittings of baths are not interchangeable unless the obliqueness of the tub walls and the depth and drilling agree. The styles of fittings are universally applicable, except that double bath-cocks

(Fig. 9) are never placed on Roman baths. All double cocks are provided with detachable coupling and sprinkler, which, fitted to hose, provide a means of spraying the body. Independent spray, needle, shampoo, and overhead shower fixtures, simple and in combination, with or without curtains, are made for use with the various tubs, the tub serving as a receptor for the falling water.

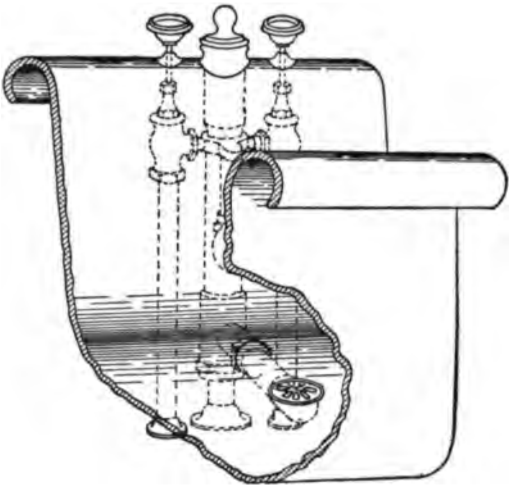


Fig. 8. Showing Central Location of Fittings and Waste Outlet in Roman Bathtub.

The cheapest serviceable bath fittings are a Double Cock and Connected Waste and Overflow. These are shown in Fig. 10. Bell Supply and Waste fittings, a special type of which is shown in Fig. 11, are singularly popular, the water being retained by a ring valve attached at the bottom of the overflow pipe, and operated by means of a knob projecting above and through the top of the waste standpipe. This takes the place of the ordinary plug and chain used with the simple overflow. The supplies are made and fitted in combination with the waste arrangement, with the valve handles projecting above the rim of the bath, the two supplies being delivered into a common yoke-piece, where they mix and flow through a common passage to the bell-piece fitted through the vertical wall near the bottom of the bath. With the usual slotted-bell delivery, these fittings are a nuisance in one respect. Water cannot be drawn into a vessel through the bell for any ulterior purpose; and as no vessel of considerable capacity can be filled at the lavatory faucets, or at a sitz or a foot bath, the sink faucets are the only resort unless a

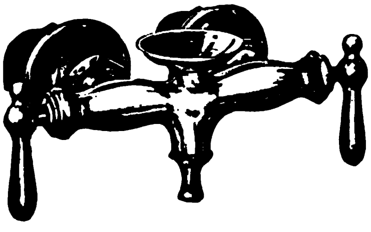


Fig. 9. Standard Double Bath Cock
Courtesy of Federal-Huber Company, Chicago

slop sink is available. Nozzle-delivery bells, which afford some relief in this respect, are made; and hand sprays used in conjunction with them avoid the expense of special shower fixtures, which would otherwise be essential if shower or spray were desired at all.

A modification of these fittings, termed "Top-Nozzle Supply and Waste" (Fig. 12), overcomes this objection to the strictly "Bell Supply" type. It has a high nozzle delivery projecting into the tub, and is fitted for spray attachment. The inward projection is much less than with a double cock, which, in a short bathtub, would occupy much needed space. The noise of falling water, obviated with the bell placed low, is the same as with the double cock; and the mixing space, intermediate between that of a cock and the regular bell delivery.

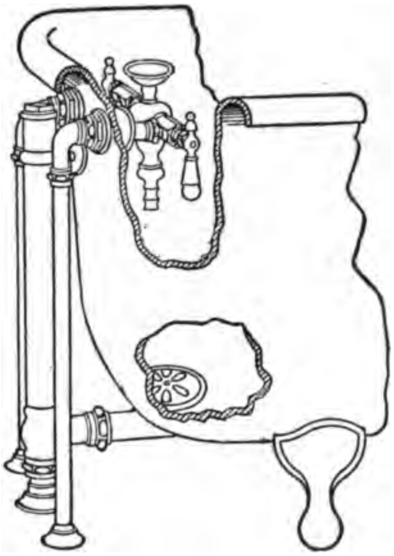


Fig. 10. Common Type of Double Cock and Connected Waste and Overflow.

An element of danger is inherent in a bell-supply outlet placed so low down as to be submerged when the tub is in use. If the supply is opened when the tub contains dirty water, and the pressure of water is lowered by accident or by opening faucets elsewhere, it is quite possible that the fouled water will be drawn back through the bell or nozzle into the supply pipes, thus, perhaps, contaminating the water for domestic use. For this reason, cocks which discharge near the top edge of the fixture, are being more frequently used as the faults of the bell fittings are well recognized.

For private use, where both children and adults are to be regularly served, the bathtub is the only fixture answering the requirements. As the physical conditions of the members of the family are, or should be, mutually known, and the tub will be regularly cleansed between baths, any possible chance of communicating humors of the skin through the bath can be guarded against. For institutions and general public use, the tub bath is open to serious objections, some of which apply as well to private use. The water for a tub bath is at its best when first drawn into the tub; and the person, before bathing, is certainly in condition to pollute it more or less. As the bathing process nears completion, these conditions are exactly reversed. Tubs used by the public may not be carefully cleansed between times of use, and the bather is ignorant of the condition both of the tub and of the person who used it previously. In institutions for the insane and feeble-minded, unscrupulous attendants have been known to bathe several persons in the same water. Large pools are better, but still not ideal; nor are they always suitable or practicable.

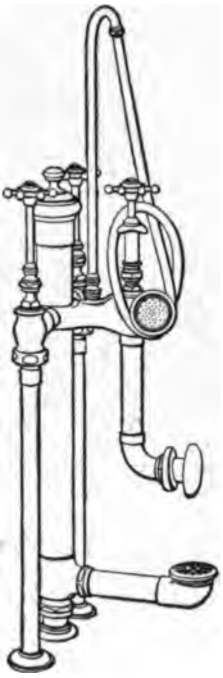


Fig. 11. Bell Supply and Waste Fittings.

Shower Baths. Shower or rain baths are commonly installed in barracks, gymnasiums, and schools, and are no longer unusual in private dwellings. Some of the objections to the tub bath, which have been stated, are entirely avoided by the shower fixture with its supply of running water. Those who have studied the hygienic effects produced by the action of jets or streams on the surface of the body, urge very strongly that the impact results in stimulating the proper action of the skin. This is the opinion of most persons who have had experience with such apparatus.

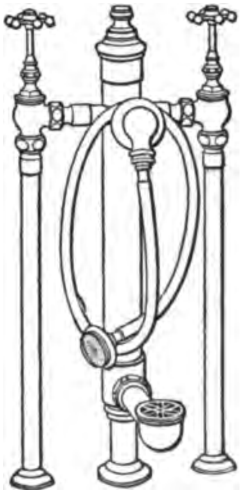


Fig. 12. Top-Nozzle Supply and Waste Fittings.

The older forms of showers, which direct the water vertically upon the head of the bather, are not so desirable as those in which the outlet is inclined and placed at about the level of the shoulders, thus avoiding wetting the head unless desired. Indeed, all the essentials of a bath of this form are met by a water-supplied rubber tube discharging at about the level of the waist over a tight floor or pan provided with a drain.

Aside from the shower baths that may be provided in conjunction with a bathtub, one type of which is shown in Fig. 13, many designs are fitted to floor-pans, called *receptors*, usually having a curtain, as in Fig. 14, thus providing for private installations a great variety of complete showering and spraying appointments. The receptors may be enameled iron, porcelain, or marble. A cement or asphalt floor, sloping to a drain, is simple and effective.

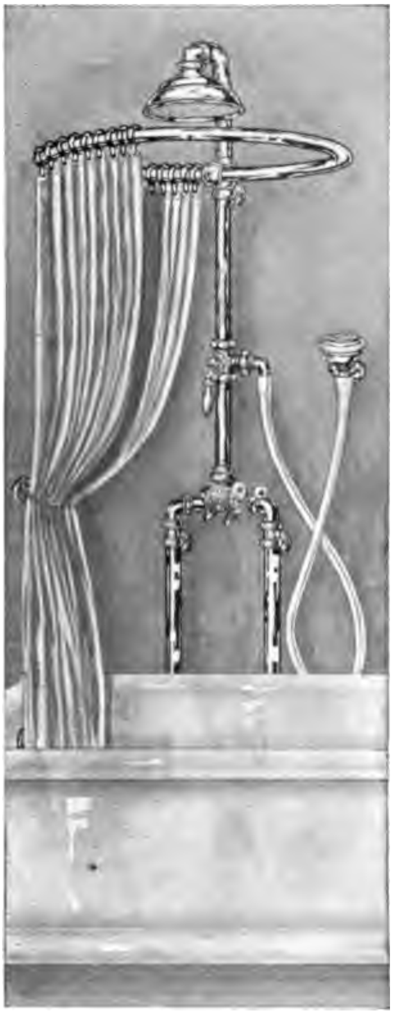


Fig. 13. Type of Shower Bath Provided in Conjunction with Bathtub. Note Spray Attachment

Courtesy of Federal-Huber Company, Chicago, Illinois

In lieu of the full curtain and regular receptor capable of providing six to eight inches' depth of water, and having tub-like supply and waste fittings in addition to the shower features, a shallow base of marble provided with a drain and having three marble sides, such as is shown in Fig. 15, can be provided with any preferred type of shower fittings. The overhead douche, already noted, set at an angle, with flexible joint for adjustment, as seen in Fig. 16, so that the body can be played on without wetting the hair, is not often fitted to private shower fixtures, as it requires considerable additional space. A rubber cap for the head enables one to use the vertical shower with a fair degree of satisfaction.

A point concerning shower fixtures and relating to the safety of the user, to which special attention should always be given, is that of the valve arrangement. If the design renders it at all possible, as sometimes is the case, one is apt inadvertently to scald himself by at first turning on hot water alone. The chances of injury in this way increase with elaborate combinations, if not carefully guarded against by the designers; and we should not take it for granted that they have provided such safeguards. As a rule, reliable makers do embody ample mixing chambers, thermometers, etc., in such apparatus, where necessary, and they regulate the control of hot-service valves, or in some other way render the improper use of them unlikely. The latter precaution is most satisfactorily taken care of by regulating valves such as shown on the side of the frame, Fig. 14, a movement of the handle to any particular point giving the exact temperatire desired.

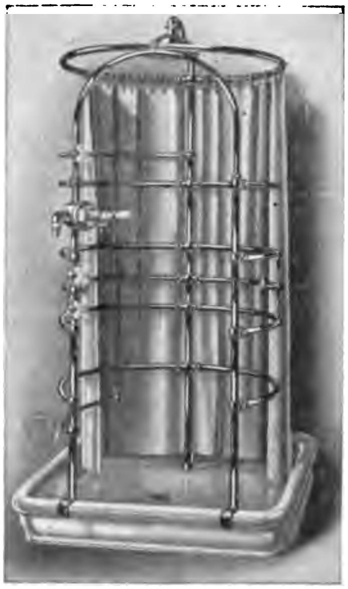


Fig. 14. Shower Bath with Curtain, Piping, and Temperature Regulating Valve Attached to Porcelain Receptor
Courtesy of Crane Company, Chicago

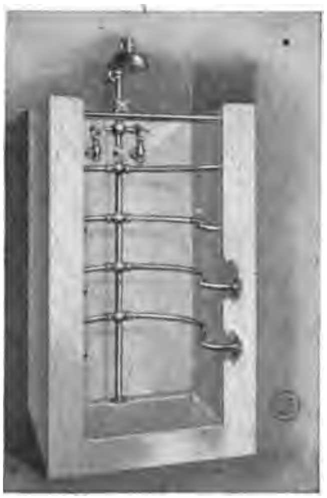


Fig. 15. Combination Needle and Shower Bath
Courtesy of Crane Company, Chicago

Sitz Baths. These are primarily for bathing the hips and loins in a sitting posture, but may be fitted with special features as ordered. Porcelain and enameled iron are the usual materials. The fixtures approximate in dimensions 15 inches in height at front and 26 inches at back, and are 26 to 30 inches wide. In the back, at a proper height, in a complete fixture, like that shown in Fig. 17, is a horizontal slit accommodating fittings for a "Liver Spray"—a wide wave-like spray of water, either hot, cold, or of intermediate temperature, as suits the person. In the bottom, in conjunction with the outlet, is a hot or cold douche, equally under control of the user. In the center of the douche, and operated independently, is a Bidet jet. These provisions are entirely separate from and independent of the regular supply fittings, but one waste fitting is used in common for all. The simple sitz bath has the regular Bell Supply and Waste, like those used on the bath, the dimensions being diminished to suit. For the extraordinary features, these fittings are merely adapted in a way to give the user convenient control. For all but the simplest fixtures, the control appliances are invariably fitted through the rims, the valve handles being provided with proper indices to guide the user. Bidet jets in combination with sitz-bath fittings, have to a great extent curtailed the use of separate Bidet fixtures. Bidet jets have often been added to water-closets, but a satisfactory application cannot be made to a closet. Separate Bidet fixtures are now rare, but are furnished by

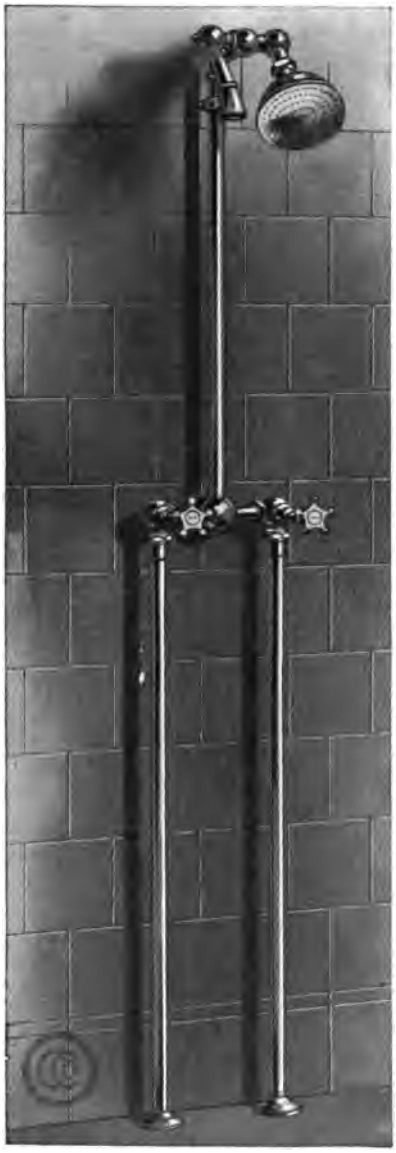
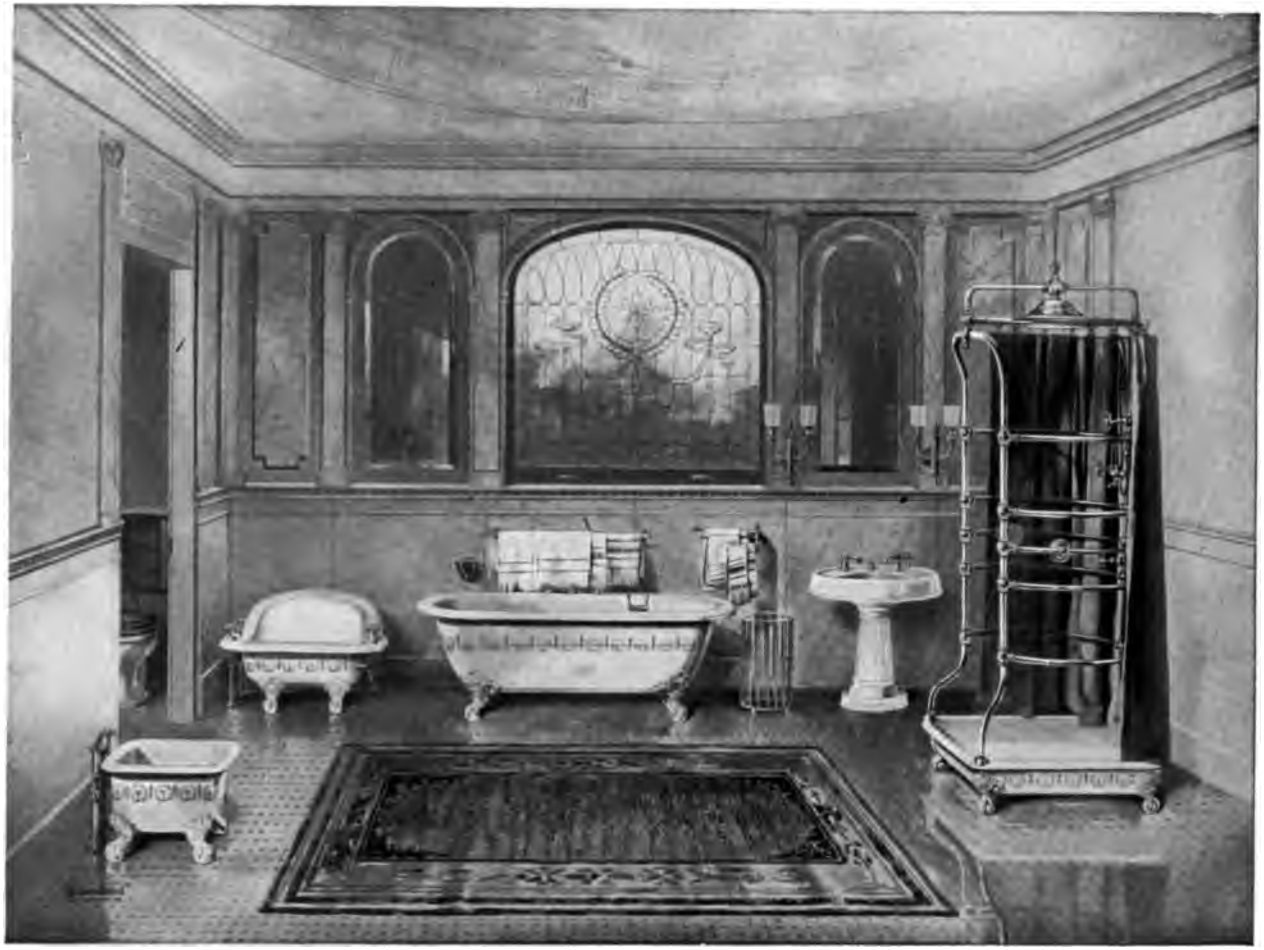


Fig. 16. Shower Bath Fitting with Shower Head and Douche Adjustable
Courtesy of Crane Company, Chicago



TYPE OF MODERN AMERICAN BATHROOM WITH LATEST APPROVED FITTINGS
Courtesy of Federal-Huber Company, Chicago

fixture makers; and in isolated cases, where frequent or regular use is necessary, are preferable to any combination with a fixture used for other purposes.

The sitz bath is conveniently used for a foot-bath, thus making this fixture doubly useful. Indeed, the sitz bath is a more comfortable means of bathing the feet than is the foot-bath itself. Children's bath-tubs, small, and elevated by legs to the height of a lavatory, are made, but no well-defined demand exists for them. They give greater convenience to the nurse, the use of less water, and quicker filling and emptying, but these are the only points in their favor.

Foot-Baths. The foot-bath is a small rectangular tub with proper feet and rim, furnished with supply and waste of the regular bath pattern, diminished to suit. The sizes average say 12 inches deep, with 20-inch sides. The feet make the total height about 18 inches. Fig. 18 gives a good idea of the usual enameled-iron foot-bath fixture. Enameled iron and porcelain are the usual materials. They require even less water than the sitz bath, but, as before said, are not so convenient for the purpose as the sitz fixture, and are not installed except in the most spacious and elaborate bathrooms. The foot-bath would serve admirably as a child's bath, except that it is too near the floor for convenient use as such.

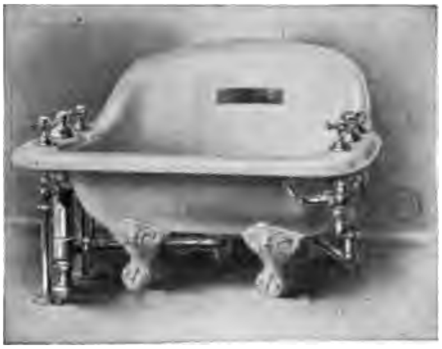


Fig. 17. Enameled-Iron Sitz Bath with Complete Fittings
Courtesy of Crane Company, Chicago

Bidet Fixtures. The majority of leading fixture makers do not now catalogue these. They consist essentially of a pedestal like a closet pedestal, with bowl and rim contracted in the center, giving an outline something like the figure 8. Proper fittings to operate the jet and waste are provided. Porcelain is the material. As mentioned before, Bidet jets are furnished in combination with receptor shower fixtures, as well as with sitz baths.

Drinking Fountains. Drinking fountains are now frequently used in stores, schools, and residences, the various fixtures adapted to such installations being readily obtainable. The basins or drip-slabs for public indoor fountains, are often cut to order by the manufacturer; and the cooling and faucet arrangements are provided by the plumber. Porcelain, enameled-iron, and marble fountains of stock designs are made. Most municipal regulations for schools require rough-like basins to be provided with sanitary drinking cups, Fig. 19, to prevent infection. The fixture shown in Fig. 20, consisting of solid porcelain, in which the drain-slab and the high back constitute a single piece, is of recent design, presents an excellent appearance, and has the advantage of being easily kept in immaculate condition. The two fountain drinking cups are built low to give a plentiful flow without spattering, and the compression cocks below are easy of manipulation.

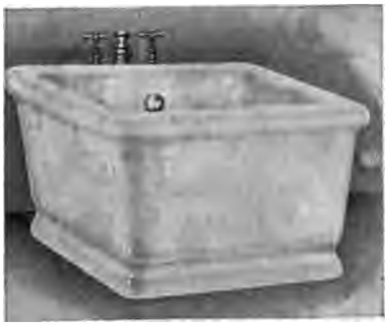


Fig. 18. Porcelain Foot Bath with Standard Fittings
Courtesy of Federal-Huber Company, Chicago

One device which serves well for common use, is the ordinary lavatory, provided with a stiff perforated bottom fitting extending well up toward the top of the bowl. This, with a proper faucet on the slab, and a cup-chain fitted to the extra faucet-hole, makes a useful but not attractive fixture.

Recessed porcelain and enameled fountains designed to be placed in wall niches, and having concealed connections, as suggested by Fig. 21, are neat, and require very little room outside the finished wall line. Countersunk slabs with strainer waste, with back either integral or separate, as design or material dictates, are made in marble and porcelain. Marble fountains are adaptable to any location, because the slab and back can be cut to any shape or dimensions preferred. The fountain proper, faucet, cup, and pipe waste connection, with strainer, are all that is supplied by the makers.

A type of fountain shown in Fig. 22, is provided with a flowing jet of water from which one can drink without placing the lips in contact with any metal surface. The small central bowl or cup is constantly submerged and cleansed in the stream of water which passes outwardly over it, thus avoiding the danger incident to the common use of the same drinking cup by many persons. The surface does not afford lodgment to possible germs of disease, which are most liable to transmit contagion when allowed to become dry and adhere to a surface. In fact, city ordinances require that all public drinking fountains be of the sanitary type.

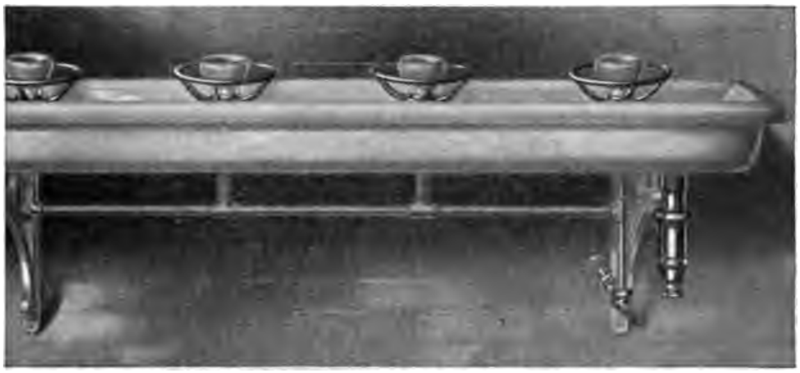


Fig. 19. Enameled-Iron Fountain Receptor with Self-Closing Heads Particularly Designed for Schools and Other Public Places
Courtesy of Crane Company, Chicago

Lavatories. Lavatories are made from porcelain, enameled iron, marble, and onyx, in numerous patterns. The number of designs is so large that they are best understood if considered in the classes into which they may be divided. In marble and onyx fixtures, the slab, back, and bowl are necessarily separate pieces. In any but very accurate fitting and erecting, the unavoidable joints soon invite the accumulation of dirt. Poor workmanship, settling, abortive countersinks, and faucet bosses not cut free within the countersink, have in many cases

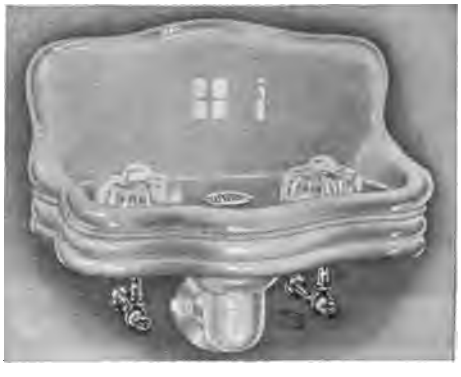


Fig. 20. Double Vitreous China Fountain with Integral Back and Separate Trap Shield
Courtesy of Federal-Huber Company, Chicago

brought slab types of basins into unjust repute, or, at least, have given basis for strong talking points against them, which have been effectively so used. If made and installed in the most approved manner, these styles, properly cared for, offer little reason for severe criticism. One fact, however, must be borne in mind when comparing marble with other materials used for plumbing fixtures—namely, that marble is *not an impermeable stone.* Nearly all marbles (excepting only the very hardest and most dense) are quite absorbent, and depend upon the surface finish given to the

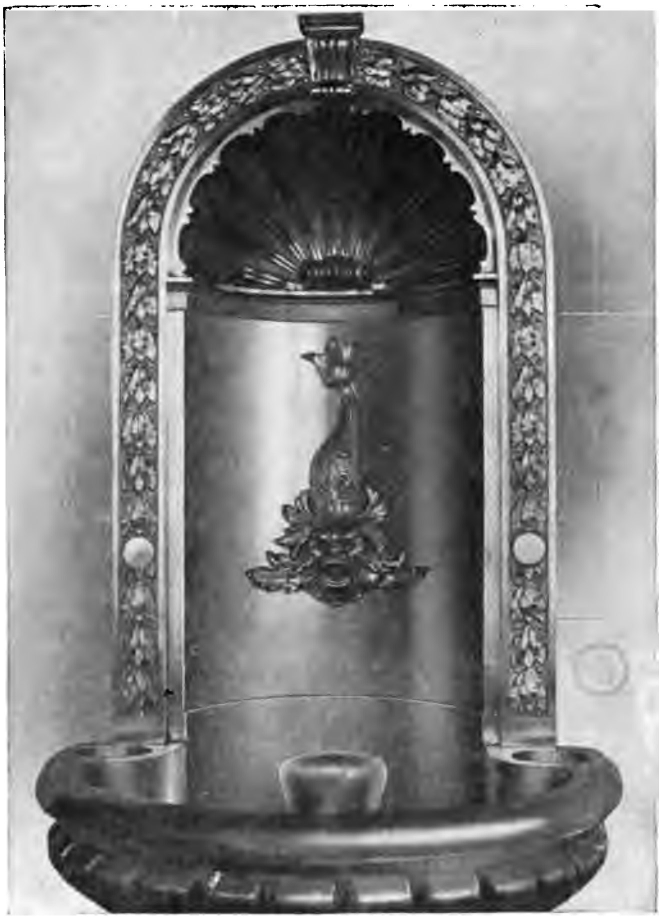


Fig. 21. Cast Bronze Recessed Drinking Fountain
Courtesy of Crane Company, Chicago

slab to resist the entrance of liquids into the body of the stone. As soon as the surface becomes roughened by wear, the greasy and acid wastes penetrate into the pores, and the marble becomes permanently discolored. Only a limited observation of the bad condition of marble floors or urinal slabs which have been subjected to use for a few years, is necessary to confirm this statement.

Ordinary Tennessee, Veined Italian, Hawkins County Tennessee, and Statuary Italian marble, range in cost in the order mentioned. Fancy imported marbles and onyx are much more expensive. Tennessee marble varies in color from grayish brown to very dark reddish brown, uniformly intermixed with light specks. The Hawkins County marble is bright reddish and white-mottled. All the ordinary materials are cut in stock sizes, and may also be had to order, like the more costly, in any size and shape desired. The type with apron or skirting, has legs, and the slab is supported by the skirting. When supported by brackets or leg-brackets, the strength of the slab is alone usually depended upon for support between the bearings. If brackets are properly spaced (as far from the ends as fittings will permit will never be too close together for any ordinary size), the weight is so balanced as to leave very little sagging strain on the slab.

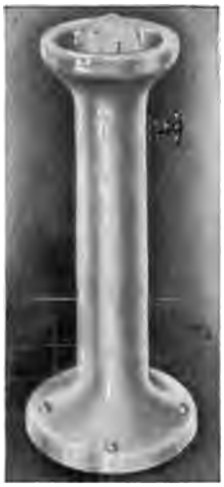


Fig. 22. Enameled-Iron Fountain
Courtesy of Federal-Huber Company, Chicago

Built-in lavatories similar to Fig. 23 are often used and with appropriate fittings are very effective.

Porcelain and enameled-iron lavatories have bowl, back apron, and soap-cup in one piece. The pedestal of the lavatory illustrated in Fig. 24 is separate, of course, and no back is required, but the general features of integral construction are shown. The only injury possible to them is the marring or fracture of the glaze or enamel. Porcelain and iron lavatories, which can be furnished at reasonable cost, unlike those of marble, are adapted to pedestal support; and some very desirable patterns are therefore made in these materials only. Neither pedestal nor wall lavatories without backs, are suitable, except where the wall or wainscoting is of marble, tile, or other waterproof material.

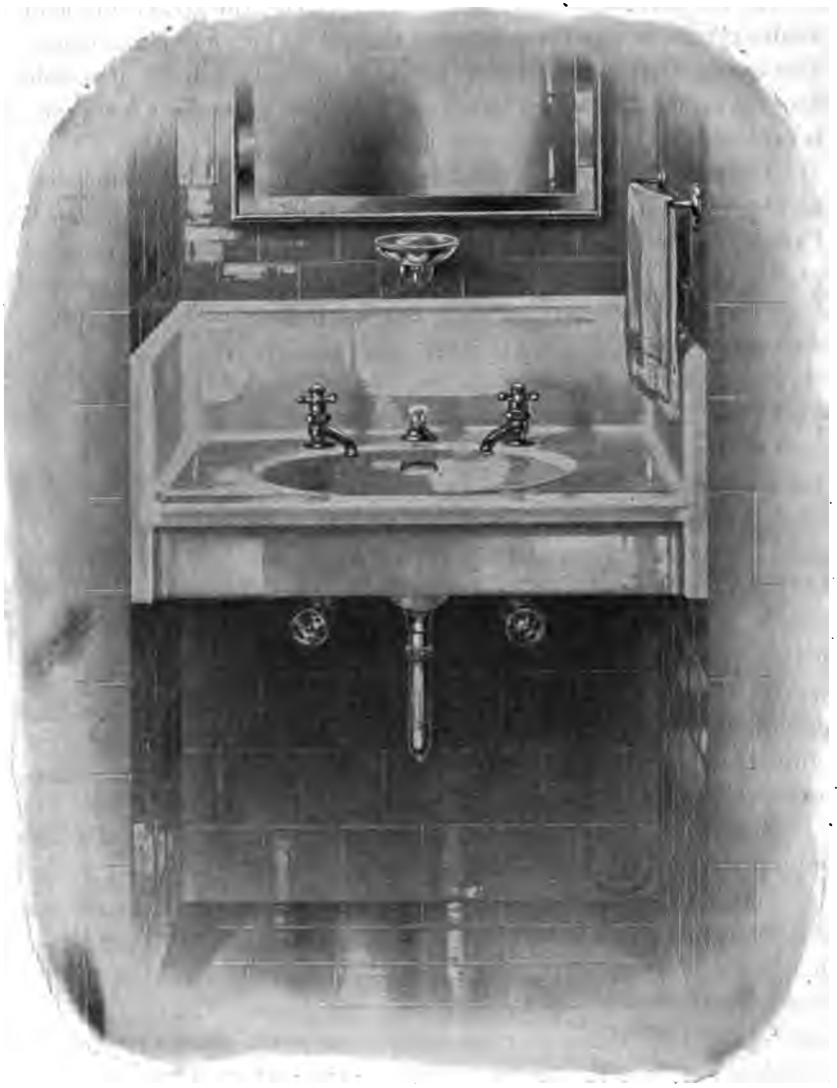


Fig. 23. Solid Porcelain Lavatory with Self-Closing Basin Faucets and Direct Lift Waste
Courtesy of Crane Company, Chicago

To provide for leaving the floor clear and free of obstruction, lavatories supported on brackets or hangers, as indicated in Fig. 25, with supply, waste, and ventilating pipes fitted on or into the wall, are best. If found practicable, a neater job results if all pipes leading to and from pedestal lavatories are carried through the pedestal. A supply and waste run to the floor is generally far easier and cheaper to secure than the fitting of all pipes to the wall.

The purchaser seeking iron or porcelain fixtures, has no choice of styles beyond that which the market regularly affords. If he prefers the workable materials, he should insist upon certain features of design which are essential to the best service. Abrupt edges and sharp corners should be avoided; the slab ought to be at least 1½ inches thick, and the back not less than 12 inches high; the general dimensions must be as liberal as space will allow or the service demands (not less than 22 by 32 inches for a 14 by 17-inch bowl); the countersinking must be deep, $\frac{3}{16}$ to ¼ inch; the faucet bosses must not join the general border level at all; the faucets must not be less than 12 inches apart, nor so near the bowl that it will be difficult to secure them to the slab; nor may they be placed so close to the back as to make repairing troublesome with any type of Fuller faucets; the joint surface of the bowl must be ground to fit the slab, and provided with not less than four well-drilled anchor-holes for clamps to secure it.

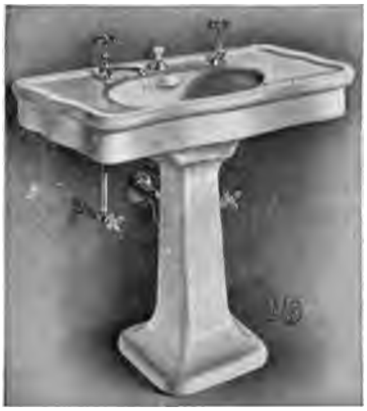


Fig. 24. Lavatory on Pedestal
Courtesy of Federal-Huber Company, Chicago

Round bowls were formerly quite generally in use, but are now almost relegated to memory. The width of slab needed for a roomy, round bowl is too great; and at best the arms of the user must be cramped in a somewhat vertical and awkward position, while the smaller sizes are very uncomfortable in this respect. The sudden opening of the faucet when the bowl is empty, is likely to ricochet water with annoying results. This is caused by the water striking the curved bowl at a tangent; the action is not peculiar to the circular bowl; the oval or crescent, or, indeed, any shape of bowl that presents a curved surface to which the faucet stream is tangent, favors the same result; the ovals in integral fixtures are the most annoying. Marble and onyx have an advantage over porcelain and enameled lavatories so far as ricocheting is concerned. The opening in the slab is not so large as the bowl, and thus a horizontal overhanging ledge is formed all around, above the bowl, which generally intercepts the water in a way to keep it off the floor and person. Porcelain and enameled fixtures have not this virtue. The bowl surface, being integral with the slab, is uninterrupted and continuous; hence ricocheting is more violent with them than is possible with the separate bowl.

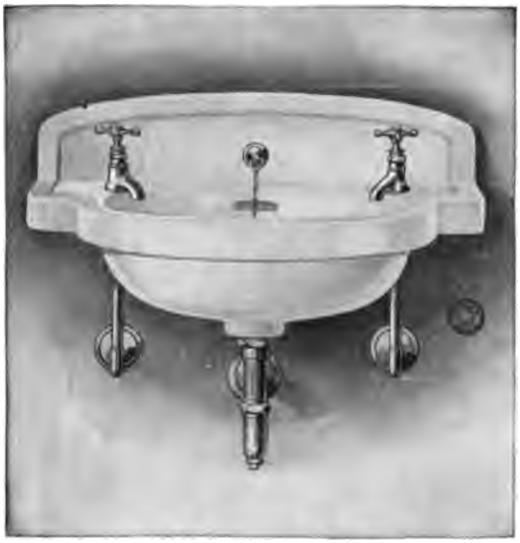


Fig. 25. Vitreous China Lavatory with Integral Back
Courtesy of Trenton Potteries Company, Trenton, New Jersey

Oval bowls are now in general use on all types of lavatories. They employ slab space to the best advantage, and are the most convenient for use. The crescent or kidney shape, illustrated in Fig. 26, is, however, as far superior to the simple oval bowl as the oval is to the round. It permits the forearms to lie in a natural and most convenient position when dipping water to lave the face. This form of bowl should be accompanied with a scalloped or recessed front. The D-shaped bowl, and other bowls embracing the prime feature of the D-shape, while not so graceful in appearance, are, without exception, to be preferred, on the score of utter absence of ricocheting when the faucets are properly placed. The D-shape, a transverse section of which is shown in Fig. 27, has a semi-oval front, with the end lines continued parallel some distance past the major axis, and with a straight-line back nearly vertical. This form gives a nearly flat surface in the bottom between the back wall and major axis, on which surface the stream strikes and breaks when the bowl is empty. A depth of water is quickly formed under the stream, which checks any spraying or spattering.

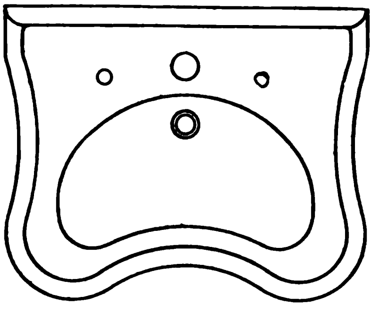


Fig. 26. Plan of Lavatory Slab with Crescent or Kidney-Shaped Bowl.

The traps used for lavatories are lead or brass (either cast or tubes), or combinations of these materials, plain or vented or of anti-siphon design. One trouble with lavatory trap ventilation, is the difficulty of obtaining a vertical rise directly above the trap. These vent connections should be carried as nearly vertical as possible, as high at least as the bottom of the lavatory slab, before any horizontal run is made; otherwise the choking of the waste pipe would float solid matters into places from which gravity would not dislodge them. In the absence of water-wash in the vent pipe, these solids would obstruct the vent and defeat its purpose. This danger is not given due attention by many plumbers. The patent and horn overflow bowls, with plug and chain, are the cheapest effective means of controlling the overflow and waste from the bowl. The standing waste, of essentially the same design as the waste fitting for a bathtub, with the body fitting projecting through the slab at the rear of the bowl, is perhaps the most satisfactory waste and overflow arrangement. Various schemes for operating basin stoppers by means of levers and swivels, are employed; but none of them has come into more than limited use.

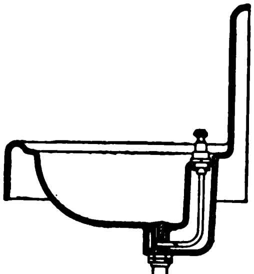


Fig. 27. Transverse Section of D-Shaped Lavatory Bowl.

Basin faucets, aside from special designs, are made on three general operating principles—(1) screw-compression; (2) eccentric action without springs; and (3) self-closing. They are also made in two types—with regular and low-down nozzles. All of these are represented in Fig. 28. The regular type has the nozzle some distance above the base flange, and screws into, or is cast on, the body. The low-down type has its nozzle with a flat bottom, hugging the slab as closely as practicable. The objection to the low-down is the inaccessible narrow space between the nozzle and slab, which becomes filthy and is difficult to clean. High, projecting nozzles obstruct the space over the bowl, especially when washing the hair, but are otherwise most satisfactory. The high nozzle gives trouble with patterns of faucets that separate in the body for repairs, such as the Fuller type, which closes rapidly with pressure. The fault, however, is often that the slab is so shallow as to necessitate the faucets being placed too close to the back to turn without removing the nozzles. If these are cast on, removal of the whole faucet is required before it can be separated. Some faucets are made with union joint in the body, thus avoiding such trouble; but these are not widely used.

The false economy which often dictates the purchase of a small slab, generally also prevails in the selection of its trimmings. Compression faucets close against the pressure, and are slow in action, causing practically no reaction. They are generally responsible for the omission of air-chambers on supplies of medium pressure. On account of their slow action, they are suitable for high pressures although but little weight is given this fact by the trade. The features essential to good, lasting service in the compression faucet, are: a cross-handle, a stuffing box, a raised seat, and a swivel disc. Self-closing faucets of various patterns are made with a view to preventing waste of water, the intention being to compel the user to hold the faucet open only as long as water is needed, and to insure automatic closing when it is released. There are none such except the crown-handled, that an ingenious person cannot find means to hold open at will; yet, withal, self-closing faucets are of great value in reducing wastage. A rabbit-eared faucet can be kept open by placing a ring over the handles while squeezed together; the telegraph bibb, by weighting down or tying up the lever; and the T-handled, while not so easily controlled, can be tied open by a lever secured to the handle. The crown-handled design can be operated with ease by the hand of the user, but does not readily lend itself to unauthorized control by means of a mechanical stop. Self-closing faucets require strong and well-designed springs to close them against the force of the water. They have sometimes come into disrepute through leakage for lack of adequacy in this feature of their construction.

Lavatory supports should have positive means of leveling the slab, such as set screws, screw-dowels, or whatever adjustment the kind of lavatory and support may be best suited to. Lavatory brackets are generally at fault in having limited bearing at the bottom of the wall-face. This point of the bracket is where all the strain is thrown against the wall, and the effect is noticeable if the upper end springs away ever so little. Full-length brackets are not open to this criticism, but they interfere with the washboard or other finish next the floor.

Sinks. These are made in four general classes according to the purpose to be served—namely, Kitchen, Pantry, Slop, and Factory or Wash-Sinks. The materials used are:—Porcelain; enameled, galvanized, and painted cast iron; enameled, galvanized, and painted wrought iron; brown glazed ware; copper; slate; soapstone; various compositions; and occasionally wood. Porcelain and enameled cast iron are most used, galvanized and painted sinks being confined principally to factory use. Sinks of extreme length, in one piece, or sectional, 6 to 8 inches deep, as shown in Fig. 29, with supply and faucets over the center line or at the side, belong to the factory class. There are roll-rim patterns, with bracket support and iron back, and with faucets fitted through the back. These are generally 8 inches deep and about 20 inches wide. The installation shown in Fig. 29 is particularly good on account of the skeleton character as it will collect little dirt.

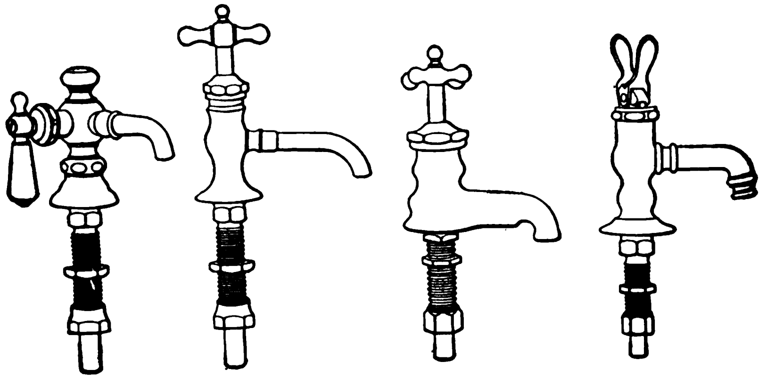


Fig. 28. Common Types of Basin Faucets

Kitchen sinks vary in size according to general requirements. Common sizes are 18 by 30 inches and 20 by 30 inches. The depth ranges from 6 to 7 inches. There are two types of iron sink—flat rim, with outlet at end; and roll-rim, with outlet in center. Neither style of outlet is always desirable as to connection; but the center outlet drains more directly. The flat-rim is not provided with legs. Cast legs were formerly furnished, being attached to the sink by slipping into dovetails. When legs are desired for this type, the plumber provides gas-pipe legs, with or without a top frame. Iron splash-backs are provided for flat-rim sinks, but not of the deep pattern in which air-chambers may be placed. Plumbers drill these sink rims to attach brackets or legs. and sometimes also to secure to them hardwood capping or drainboard. Hardwood drainboards are generally provided by the plumber's carpenter. Hardwood splash-backs, set free of the wall to permit circulation of air behind the fixture, are also provided. Sometimes marble splash-backs are provided. Marble is best, but is not in keeping with a flat-rim sink. The back may extend to the end of the drainboard, as represented in Fig. 30, or merely cover the length of the sink. Omitting the back behind the drainboard, is not often done. The drainboard should be free of the wall when the back is not extended. Iron sinks, with roll rim on front and ends, are furnished with drainboards suited to attach to either or both ends. These may be added as an after-consideration, or changed from side to side at will, if there is but one drainboard, or removed entirely, without marring the looks or service of the sink. This interchangeability commends itself to both plumber and customer.

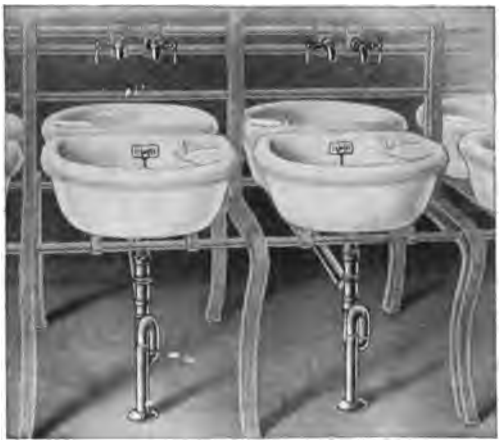


Fig. 29. Individual Factory Lavatories
Courtesy of The Trenton Potteries Company

Roll-rim sinks, with the end recessed to receive a drainboard, are also made, but in any subsequent change of location require setting in the original position, so far as the drain is concerned.

Open strainers are most frequently fitted to sinks, in which case the sink cannot be then used for washing dishes, but merely serves as a support for dishpans and other vessels and as a catch-all for drippings from the drainer. Hence the open-strainer sink must be large enough to accommodate suitable washpans, etc., while one fitted with a plug-strainer should be relatively small if it is designed to use the sink proper as a washpan. A new form of sink waste connection is now a feature of the better class of enameled sinks, in which the connection is made by means of a spud and coupling something like the ordinary lavatory coupling. In it the strainer is held down in a way less likely to cause injury to the sink lining at the waste hole.

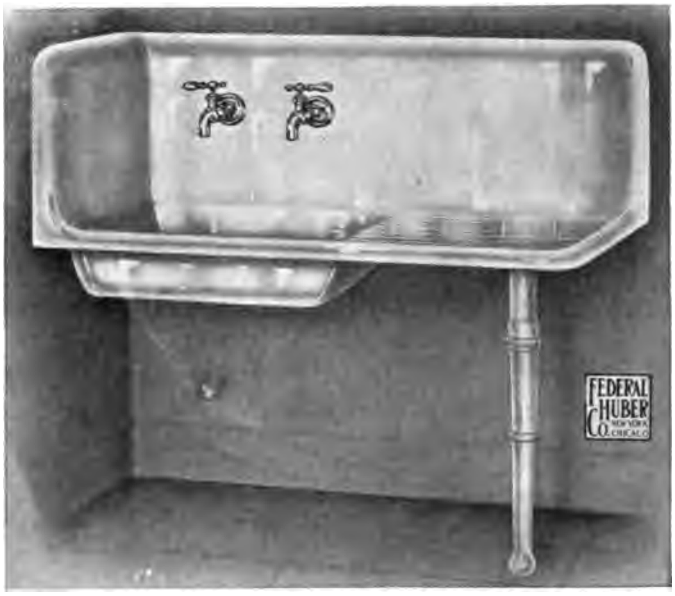


Fig. 30. Roll Rim Enameled-Iron Kitchen Sink Supported on Brackets. Splash-Back Omitted behind Drainboard

The use of wooden sinks in large installations, such as hotel kitchens and restaurants, is not unusual, the theory of their use being that less breakage of crockery occurs, by reason of the softness of the material. However, because of the objection to any porous material which retains moisture and is subject to decomposition, wood is never suitable for this use, though with copper-lining it is permissible.

Rubber mats are essential for both sinks and drainboards having enameled or glazed surfaces, in order to avoid accidental injury to both the fixture and the articles cleansed. As a matter of fact, the average dwelling has but one sink, which serves both kitchen and pantry purposes. Dual service is not always satisfactory, however, as no sink can be well adapted to both uses for a large family.

Porcelain and iron sinks have generally been supplied with loose backs; but sinks of one piece—that is, with sink and back integral—are now obtainable. Sinks with integral apron or skirting all around, placed free of the wall, are suitable where the wall is waterproof.

Sinks are built from slabs of natural stone as desired, and may be with or without drainboard or skirting. They are generally provided with a high splash-back. These sinks are not limited to the patterns of a moulding room, and easily keep pace with the desires of the purchasers. Selection is confined to a choice of material.

In the use of any natural stone, such as slate or soapstone, for plumbing fixtures, and especially for sinks, it should not be forgotten that angles and rectangular corners are with difficulty maintained entirely free from deposit. Although the flat surface can be readily scoured, it is always difficult to clean the sharp angles and corners satisfactorily. The difficulty is increased by the fact that some plastic jointing material, such as putty or cement, must be used in putting together the fixture; small fragments of this material project into the angles and render the corners rough.

Air-chambers may be cast in iron sink-backs, or independent cast or pipe chambers fitted in the cavity. The ordinary sink-back is not well suited to the convenience of the plumber where supplies to any fixtures pass up behind the sink. The faucet-holes cannot be changed, and slots for pipe are not provided at the top edge. Sawing these gaps after the goods are enameled, leaves the fixture with an unfinished appearance. The proportion of shank to the handle of faucets of the Fuller pattern used on sink-backs, must be such that the handles will turn straight back.

A popular fixture of comparatively late design, adapted for small dwellings and now made in the cheaper materials, is the kitchen sink in combination with a single laundry tray, Fig. 31. In this, the drainboard serves as a cover for the tray when the sink is in use. Sinks have also been supplied in combinations with lavatories, one sink being placed in the center or at the end of a battery of lavatories.

A pantry sink (Fig. 32) should always be provided with a drainboard. It is a smaller fixture than the kitchen sink, and is nearly always of the plug-strainer and overflow type. Its faucets are generally of the high-nozzle barber-shop type, but of smaller capacity and better adapted to rinsing than are kitchen-sink faucets. Indeed, the pantry sink proper need not necessarily differ at all, unless in size from sinks used for other purposes. Every feature of its trimmings and setting is intended to best serve the butler's needs.

The waste matter from the butler's sink is not like that from the kitchen sink; hence the waste pipe is not necessarily so large, nor is a grease-trap so badly needed. Grease in considerable quantities finds its way into kitchen-sink waste pipes. It floats on the stream of waste water as it travels through the pipe, and, being always next the interior surface, either adheres thereto on contact, or by a reduction in temperature is chilled and congealed and thus clings to the pipe walls. Successive layers of grease are in this way accumulated, and the bore of the pipe is finally reduced so much that solid matter easily completes the stoppage. Forcing out, and then filling the pipe with boiling lye water, and again flushing with hot water, will usually remove most of the obstruction. Sometimes the lye loosens the grease in chunks, which clog the pipe seriously at the first favoring point, and the pipe must then be cleaned manually.

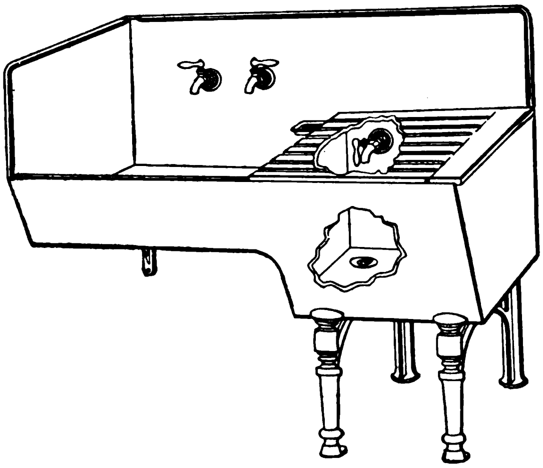


Fig. 31. Kitchen Sink and Single Laundry Tray Combined.

When once choked with grease, the pipe must ultimately be opened and cleaned by hand, often at material expense when long lines are deep underground. To avoid this trouble, various traps (of which two examples are shown in Fig. 33) have been designed to separate and collect the grease, either by flotation alone or by chilling and flotation combined—generally by the former. The former were previously improvised by the plumber, being placed in the drainpipe just outside the building. This location left too much pipe subject to choking between the grease-trap and the sink; and the trap itself often became a generator of bad odors in warm weather.

The grease-traps now commonly furnished are placed in the kitchen under the sink, and frequently serve as the regular trap for the fixture. The grease is easily removed by lifting out the container or by skimming from the top. Hinged bolts with thumb-nuts secure the covers so that they can be easily and quickly opened and securely closed.

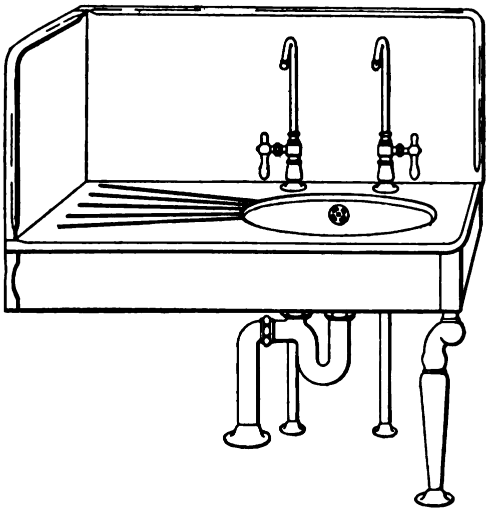


Fig. 32. Pantry Sink.

Traps which chill the grease are not used so much as those acting by simple flotation, but they do the work perfectly. The chilling proccess is accomplished by means of a water jacket through which the cold-water supply passes. The water entering low, surrounds the wall of the pot trap within, and passes out high up on the opposite side (see fixture at left in Fig. 33). Circulation—or, rather, change of water—in the jacket, is dependent on the amount of water used at the fixtures.

The usual slop sink is 18 by 22 inches and about 12 inches deep. Generally it is furnished mounted on a trap standard, as in Fig. 34, which serves the double purpose of support and waste-trap.

Care should be taken before installing a fixture placed upon a trap standard, to examine carefully whether the seal of the trap is provided for by suitable interior partitions. It is not uncommon to find defects in the casting, if of iron or brass—or in the porcelain, if of that material—which would seriously affect the maintenance of the

water seal. In fact, it is desirable in connection with slop sinks, as with all other fixtures, that the trap be of such a form as to show clearly, even after being set in place, the position of the various portions which constitute the trap and maintain the water seal.

The waste pipe for slop-sinks is never less in diameter than 2 inches, and is usually 3 or 4 inches. The outlet is invariably through an open strainer.

Slop sinks are made in all the materials common to other fixtures except natural stone. These sinks are to the chambermaid what the kitchen sink is to the cook. The shape and liberal-sized waste are well adapted to removing slop and scrub water. In the complete fixture, the sink is provided with an elevated tank and flushing rim to cleanse the fixture walls; also with hot and cold supplies for drawing water, rinsing mops, etc. The supplies are usually connected between the valves, and terminate with a long spout with pail-hook and brace. The spout supports the pail over the center of the sink while filling. The ordinary slop sink is provided with hot and cold faucets; and as the rims of the cheaper kinds are plain flanges, no tank flushing is possible.

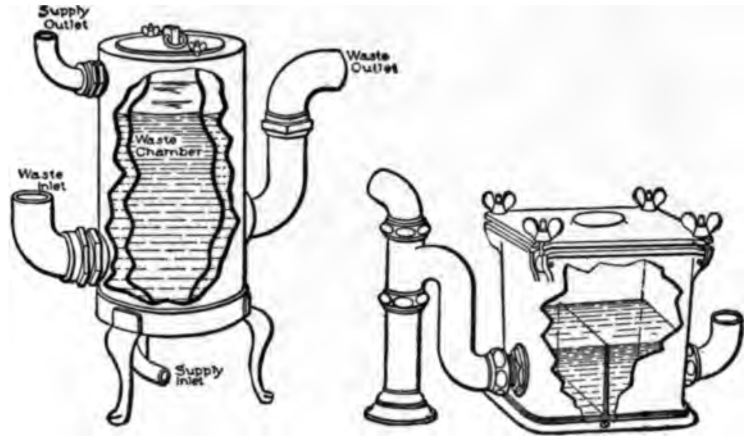


Fig. 33. Types of Kitchen Sink Traps for Separating and Collecting Grease.

Laundry Trays. These are made in all the materials used in other plumbing fixtures. Wood trays were formerly common but their unfitness because of absorption and odors, coupled with the increase in cost of lumber and the lessening in cost of the better materials, has effectually driven them out of the business.

The same inherent objection may be urged against the use of wood covers as obtains against that material for the body of the fixture.

Trays are made singly and otherwise, but generally used in sets of two or three, except in the combination with sink already described. They are supported by a center standard or a metal frame, as best suits the material used.

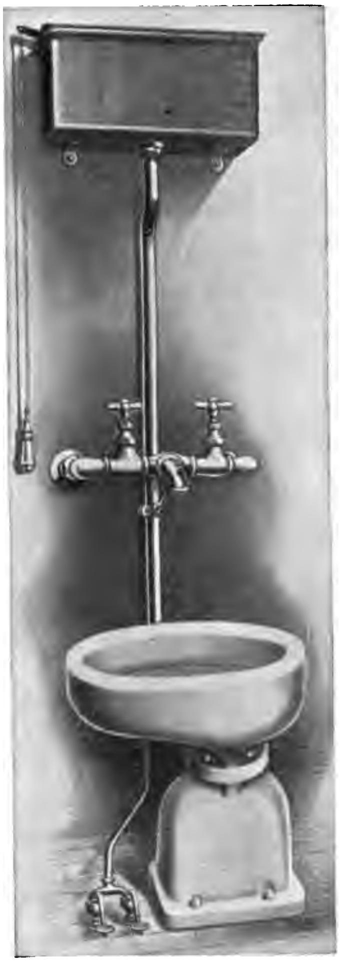


Fig. 34. Slop Sink Mounted on Trap Standard
Courtesy of Federal-Huber Company, Chicago

Some means of attaching wringers are provided, if possible. The waste is usually 2-inch. One trap answers for a set of trays. The size is about 26 by 30 inches at top and 15 inches deep. The walls are all nearly vertical except the front, which inclines about 30 degrees, making the width at bottom considerably less than at top. Some makers furnish one tray with each set, designed to serve as a washboard, the interior of the front wall being corrugated like the surface of a portable washboard. The inclination of the front is about right for scrubbing, whether the tray or an ordinary board is used, and the supports place the top of trays convenient to the work.

All trays were formerly made with faucet-holes in the back; and the plumber furnished a hinged cover. Side-handle faucets were necessary to allow the cover to close, as holes for top-handle faucets would be so low as to make useless too much of the space above them. The faucet-holes were seldom fitted water-tight. Holes are not now made in trays unless ordered, and the side-handle wash-tray bibb is disappearing. They were always annoying. If placed with the handles right and left as intended, the seat could not be examined, and no reaming or dressing of the faucet seat could be done without removing the faucet. When placed with the faucet handles facing each other, they were wrong-handed and too close together. It was awkward to supply air-chambers—especially so when all the faucet holes were equidistant from the top. When placed for one line of supply above the other, one line of holes was too low. These objections combined brought about the practice of omitting the covers, putting the supplies over the trays, and using regular sink faucets. Overflows are provided only when so ordered.

Enameled backs with air-chambers and faucets are supplied with roll-rim enameled-iron trays. A complete set of three trays, with all attachments and fittings, is shown in Fig. 35. Flat-rim trays are made with or without faucet-holes, and are intended to have a hardwood frame to secure them rigidly. The wood frame and cover can be had with the fixture, but the plumber often supplies them. Nickel-plated or plain brass wastes and traps are furnished for trays, but the plumber can provide lead or cast-iron waste, if wanted.

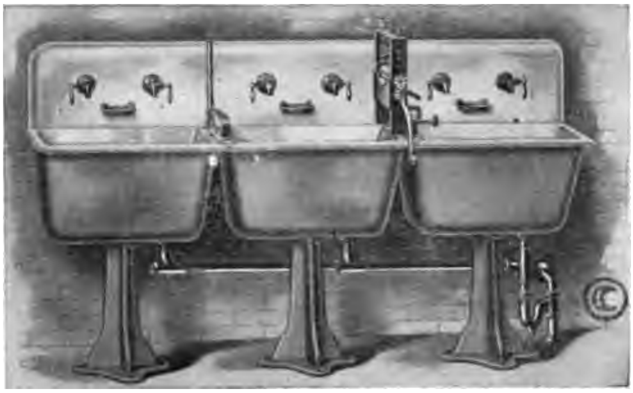


Fig. 35. Porcelain Enameled-Iron Laundry Trays with Fittings Complete
Courtesy of Crane Company, Chicago

Water-Closets. Types of water-closets are innumerable, and are separable into classes according to principles of action. Porcelain and painted or enameled iron are the materials used. Porcelain is more fragile, but has the better finish and is susceptible of a greater variety of design and ornamentation. The all-vitreous body of water-closet china of to-day is far superior to the glazed clay ware of the past, which, depending only on surface impermeability, soon cracked badly, thus permitting absorption, the forerunner of odors which no plumber's skill could prevent. Enameled iron has not so durable a surface, but will stand rough usage, and has the advantage of very seldom cracking from frost even though the water in the trap freezes.

The greater relative advantage and durability of the porcelain closet over the best qualities of enameled-iron fixtures, should not be overlooked. There is less adherence of the foul wastes to a porcelain surface than to the enameled surface. It is also a fact that enamel is subject more or less to abrasion by the use of harsh scouring materials, as well as to decomposition by uric acid and water-closet discharges, and is therefore not a very durable material. These statements can be confirmed by observation of closets which have been in use for a number of years.

Iron closets of the better forms are used most in public places, stores, warehouses, etc. The pan closet, of iron, with earthenware bowl, is not now installed. For these, a trap was placed under the floor. The pan, operated by the same lever as the flushing valve, retained water, partially sealing the body from the bowl. The flush was by the swirling of a stream which entered tangentially under the rim. The bowls were round, as is necessary in all hopper closets thus washed, for water will not swirl in an oval bowl.

The objection to the pan water-closet is principally due to the fact that the outer bowl or container is a receptacle of filth which can never be properly cleansed. When the pan deposits its contents in the lower portion of the fixture, a considerable amount of the filth is spattered upon its inner walls and is not subject to the cleansing effect of the stream of water which scours only the upper bowl. When the closet is operated, the odors from this concealed surface permeate the room in an objectionable manner.

Tall round hoppers with swirling supply are yet frequently used in outhouses and other exposed places. No other form of closet will stand such locations under like conditions. The waste-trap is not placed immediately under the hopper, as in other forms, but down below the freezing depth—five feet as a rule. The supply valve is also placed below freezing, and is operated by a pull or by seat-action. These closets are *continuous* or *after-wash*, according to the style of valve used. Such an outfit is the simple frost-proof closet of the market. Tall oval hoppers with valve and slotted spud attached, swirl or rather direct the water sideways in both directions, but not effectively. A tank supply, sometimes used for this form of closet, is also inefficient when delivered through a slotted spud under the common flanged rim. Short oval and round hoppers, with valve or tank supply operated by a pull or by seat-action, fitted to "S," "¾ S," and "½ S" or "P" traps, for lead or iron pipe floor connection, make up several hundred closet combinations, each differing in some respect from the others. These are the poorest types of water-closet.

A sectional view of the *Combined Hopper and Trap* pedestal of today is shown in Fig. 36. It is made in one piece, in both porcelain and enameled iron. This form resulted from the separate hopper and trap fixtures before mentioned. The combined form has oval bowl and integral flushing rim for tank supply.

The *Wash-out* closet is a modification of the combined hopper and trap, being formed with a dipping bed under the mouth of the bowl, which retains enough water to keep soil from sticking to the surface. The water-bed makes it necessary to discharge the contents at either front or rear of bowl. The back-outlet wash-out is most repulsive to view; in them the drop-leg, which the flush never washes thoroughly, is always in view, so that its filthy condition suggests cleansing by hand. The front-outlet wash-out, shown in section in Fig. 37, is of more inviting appearance; but the drop-leg, although hidden, is there just the same. This type is rapidly becoming obsolete.

Both the Wash-out and the Combined Hopper and Trap types have one fault in common. The trap almost always contains the soil from one usage. When the contents of the trap are flushed out after using, sometimes a similar mass refills it. Of course, two or three consecutive flushes would leave comparatively clean water in the trap, but this is not to be expected in regular usage.

On certain occasions the wash-out may serve a useful purpose on account of the water-bed. The stools of children or the sick may thus be easily observed at the will of the physician or at the discretion of those in charge, while such is impossible where the soil is submerged at once.

Pneumatic Siphon closets of various types have been put on the market. A good example of the type requiring two traps with an air-space between, is shown in Fig. 38. A specially constructed flushing tank is connected with the air-space between the traps. The falling of the flush water creates a partial vacuum in the bottom compartment of the tank, which induces siphonage of the bowl contents.

In the effort to maintain a plenum in the flushing compartment of the tank while the flush water is flowing into the closet, the air between the traps is extracted, being drawn up through the air-pipe into the tank. Atmospheric pressure presses the water out of the bowl and upper trap when the pressure below it is sufficiently reduced. This water, added to the flushing water and that of the lower trap seal, which has been drawn above its normal level in response to the vacuum, is sufficient to form the long leg of an ordinary siphon; and thus both traps would be entirely emptied were it not for the vent in the crown of the lower trap breaking the siphonage in time to save a water seal for the lower trap.

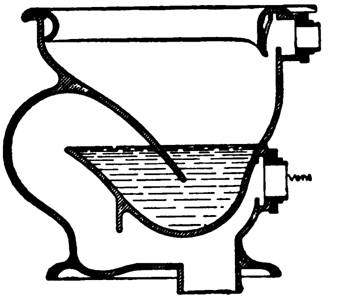


Fig. 36. Section of Combined Hopper and Trap Closet

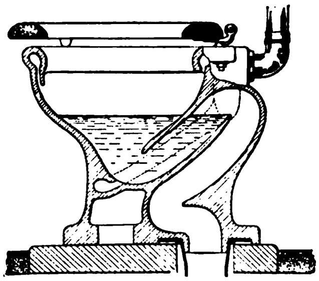


Fig. 37. Section of Front Outlet Wash-Out Closet

The upper trap with water visible in the closet bowl in repose, is supplied by the *after-fill,* thus establishing conditions for the next action. The lower trap of such closets must be back-vented, and it is essential that the upper trap have no back vent.

The proper action of the tank is necessary to operate a pneumatic closet. A closet constructed on any other principle can be flushed with a bucket, by hand, if its tank is out of order. When a pneumatic closet gets contrary, pouring water into the bowl by hand simply fills or overflows it. The outlet is air-bound, and no passage of water to the soil pipe can take place until the barrier of air between the traps is removed.

The closets now accorded first place and generally used in the best work, are of the *Jet-Siphon* type, illustrated by the sectional view, Fig. 39. These use more water than is necessary to flush other kinds of closets, because a portion of the water is employed to produce the siphonage. A channel leading from the flush-water inlet to the bottom of the trap, conveys a stream of water to the trap leg, and injects it upward therein. The water in the channel has considerable velocity, and, being discharged into the water in the trap, imparts its energy to the whole mass, which, aided by the rise due to the incoming water from the flushing rim, moves upward at a proportionally slower but increasing speed depending on the ratio of mass and jet. When the water in the trap has been lifted in this way to an extent where sufficient of it can fall over the weir into the out-leg of the trap, a siphonic movement begins, and true siphonage finally takes place. Before the closet tank is emptied, siphonage sweeps out the trap thoroughly; and what water falls back into the bowl when the siphon breaks, together with the incoming jet and flush, often causes a second siphonage.

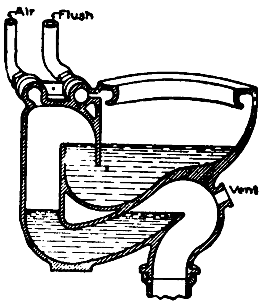


Fig. 38. Section of Pneumatic Siphon Closet, with Two Traps and Intervening Air-Space.

Accuracy in pointing the jet and in shaping the surfaces of its environment, are essential. If the surface above the jet-hole favors interference by the water flowing from the bowl, siphonage will be delayed and abortive, and may not take place at all. So, also, if the jet is not directed so as to maintain approximate concentricity in its travel through the mass of water, its energy is not expended to advantage, and failure is likely.

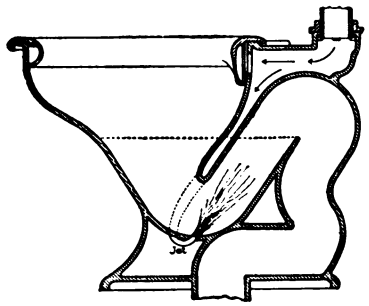


Fig. 39. Section of Jet-Siphon Closet.

There is no excuse for iron closets not siphoning perfectly. The iron pattern can be altered until it gives the best effect in practice, after which all closets cast from it should do the same. With porcelain ware, however, every closet made requires the same skill in design; and notwithstanding how perfectly the closet may be formed and the jet-hole cut, shrinkage in the kiln during the drying and burning process is apt to warp the wall and change the product so that it will not act properly. Closets of both materials, apparently perfect, often fail when first tried after installation, owing to foreign matter or fragments of enamel, clay, or iron lodging in the jet and changing its action. Usually these obstructions are easily removed by the plumber.

The jet principle has been added to the Combined Hopper and Trap closet before mentioned, producing in it a siphonic action resulting in very much improved service over that of the simple form. With the jet-action, the Combined Hopper and Trap is generally termed a *Wash-Down Siphon.* The so-called "jet" is applied in two ways. In some makes, the flush rim has an extra large and specially formed fan-wash feature, which directs down the back wall of the bowl a sluice-like stream. This stream, in addition to wetting the paper and forcing it down into the water, where it will be promptly carried out, sweeps round the curve of the bowl outlet in such a way as to lend its force to the water in the trap to produce apparent and not infrequently true siphonage.

Another form of the wash-down siphon is provided with a channel from the flush inlet, down outside the back wall of the bowl, to near or even below the water-level in the bowl, where the jet enters through a slit. The action is much the same as with the special fan-wash mentioned, but is generally superior in siphonic effectiveness.

Jet-siphon closets are not provided with vent openings in the closet proper, except for the local bowl ventilation. Wash-out traps are, or should be, vented. The simple hopper and trap should be vented in the trap. Wash-down siphons, generally, are not vented, but it is permissible to vent them low down in the outlet leg of the trap.

All closets for indoor use should have flushing rims. In all earthenware closets and in some forms of iron closets, the rims are made integral; but the iron rims are, as a rule, separate pieces, forming a water channel around the bowl. The bottom, inner edge of the iron rim hugs the wall of the bowl as closely as practicable, and the bulk of the water falls through regularly spaced serrations. Various provisions in the shape of barriers opposite the flush inlet, perforated race-way shelves along the rim above the exit openings, etc., are made to insure the rim filling and flushing properly all around.

All kinds of closets were formerly made without regard to the kind of seat to be used. Boxed-in cabinet seats, self-supporting, were universal. These gave way to seat and frame, with wall and leg support. To-day closets are commonly made with base flanges designed to support the weight of the person, and are provided with lugs or seat-shelf for attaching the seat directly to the bowl, as seen in Fig. 40. Metal post hinges are best in every way, if well made and strong. The competition goods, however—made to sell rather than use—*are* so light as neither to keep the seat in place nor to aid in holding it together under the severe strain. The hinged wood-cleat seats bolted to the closet are strong, but are objectionable because they cannot be kept dry or clean under the cleat.

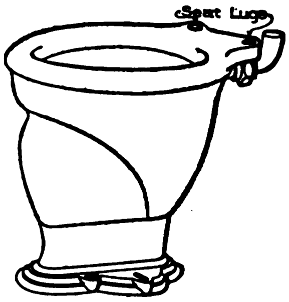


Fig. 40. Closet with Base Flange Support, and with Lugs for Attaching Seat.

Closets are operated with pull or push-button tanks requiring the attention of the user; and are also made of the seat-action type. Children are likely to be forgetful, and visitors to public toilet rooms indifferent, to such an extent that automatic closets are desirable for public places and schools.

Closets are fitted with two styles of tanks—one placed about 7 feet from the floor and serving with a flush pipe never more than 1½ inches in diameter; and the other placed low down, as close to the bowl as connections will permit. Examples of the *high-tank* and *low-tank* arrangements are shown in Figs. 41 and 42, respectively. The low tanks are wider and deeper than the high style, but do not extend out from the wall so much. The low position delivers the water at much less velocity than the elevated style, and, to secure the utmost speed and the volume necessary, the flush connection is never less than 2-inch in a low-tank closet. The rim and jet channel are proportionately larger in bowls intended for use with low tanks. High tanks are about 17 by 9 by 10 inches. Sheet lead and sheet copper are used for closet-tank linings. Some kinds of water, through galvanic action, attack the soldering of the seams in copper-lined tanks with more effect than where lead alone is used. Generally, however, copper-lined tanks give satisfaction if the copper is heavy enough (12 to 16 oz.) and properly put in. Some makers lock-seam the linings water-tight, and solder on the outside before placing the copper in the wood case.

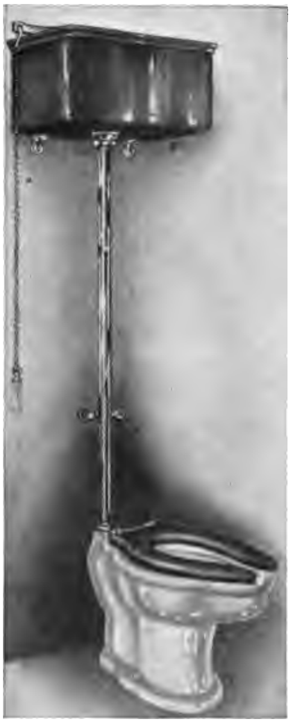


Fig. 41. Modern High Tank Closet
Courtesy of Federal-Huber Company, Chicago

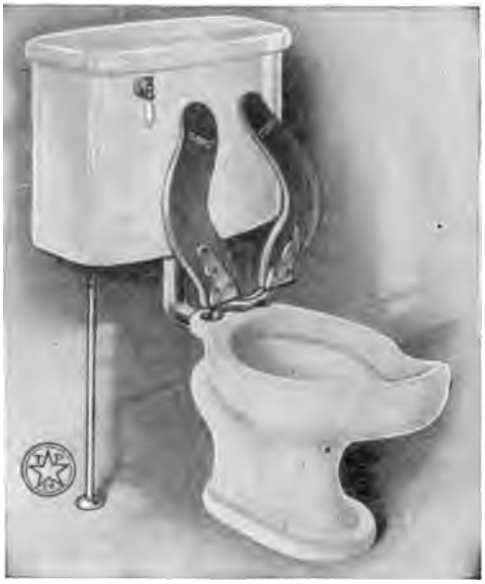


Fig. 42. Modern Low Tank Closet
Courtesy of The Trenton Potteries Company, Trenton, New Jersey

On account of the greater depth of low tanks, swelling of the wood case has, doubtless, been the cause of most of the trouble experienced with this type. When put together in the factory, the wood is very dry, and after being used for a short time, increases in height as a result of swelling from dampness. If the lining be tacked to the wood at bottom and top, injury is sure to result. Tacking at the top only is open to similar objections. It is now the practice to omit fastening the lining. Cast-iron tanks enameled two coats in and out give excellent service and so far have caused no trouble from sweating. Iron tanks with sheet metal interior lining have also proven satisfactory. Very great care has been found necessary with ball cocks for low tanks, in order to secure proper after-fill, the flush connection being too short to aid much in resealing the bowl with its drainings. Low tanks flush with much less noise than high ones, and permit placing the closet under windows and low ceilings. Low ones require more width on account of the tank, and more depth from the wall to the front, as the seat and lid must be placed far enough forward to be thrown back and remain leaning against the front of the tank. Low tanks are provided with ventilated covers; while the high pattern which is out of children's reach, is left open at the top. The fewer working parts in a tank, the less likely it is to get out of order.

A type of seat-action after-wash closet very seldom placed in private houses, is that with closed metal tank, as represented in Fig. 43. Depressing the seat opens a valve in the supply, and the water passes up through a flush pipe into a closed tank. The air in the tank is compressed until the air-pressure counterbalances that of the water. When the seat is released, the supply valve closes and a valve is opened, establishing communication between the closet and the tank. The compressed air then expels the water in the tank, flushing the closet just as a large supply with corresponding pressure would do without a tank. Closed-tank closets depend on pressure. The space occupied by the air in the tank is inversely proportional to the pressure; hence, even in heavy pressure, considerable of the tank's capacity is yet occupied by air when equilibrium is established; and the less the pressure, the smaller the amount of water it is possible to get into the tank. They are therefore not fit for very light pressures, though they sometimes serve well in the basement of a building where failure would be certain on the upper floor.

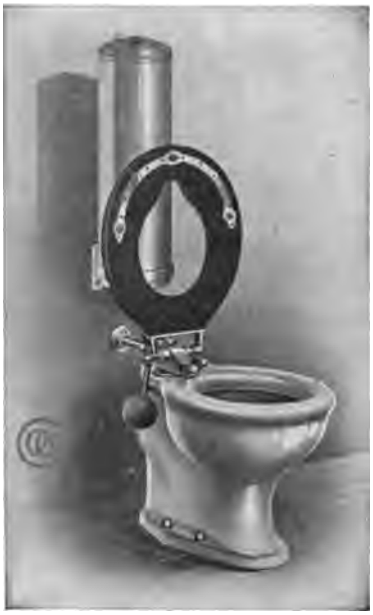


Fig. 43. Siphon-Jet Closet with Seat-Operating Pressure Tank
Courtesy of Crane Company, Chicago

Condensation on single-shell sheet metal tanks is annoying. Open tanks of porcelain and iron are used more or less, but sweating is hard to overcome. Zinc paint and ground cork finishes have been employed with some satisfaction; and drip-cup collars discharging into the flush just under the tank on high-tank closets have served in this capacity, but nothing overcomes the sweating so well as a tight wood case. Insulated metal cases and double enameled cast tank, before mentioned, will prove the only serious rivals to the wood-case tank. Some makes of the pressure-tank closet require too much weight on the seat for successful operation by a child, and children would as a rule leave the seat too soon to allow the tank to fill reasonably well. The after-fill is accomplished by projecting the flush connection into the tank an inch or more, and drilling a hole $\frac{1}{4}$ inch or less in diameter through it near the bottom of tank. The rapid flow ceases when the water-level falls to the upper end of the inward-projecting flush connection, and the after-fill drains into the flush.

The flush fittings of an open tank consist essentially of a valve to admit water to the flush pipe; an overflow always open to the flush pipe; and a lever and connection, with chain and pull or button, to open the flush valve. A simple example of these is the siphon gooseneck, with flush-valve disc on one end and lever connection at the other. Prongs extend below the disc to guide and keep it in place. The overflow is through the gooseneck. Lifting the gooseneck an instant permits enough water to flow down the flush to start the siphon through it when the pull is released. The tank then siphons to the lower end of the gooseneck arm.

Where shortness of flush pipe or form of closet requires a decided after-fill, this is secured by special provision in the flush fittings, or by leading some of the supply delivered by the ball cock into the overflow.

The supply fittings of a closet tank consist merely of a ball cock of suitable form. For light pressure, simple leverage suffices. For heavy pressure, the inlet in the valve would have to be too small, or the ball too large and stem too long, for a small tank, if simple leverage were employed. Therefore compound-leverage cocks are usually substituted where the pressure contended with is over 30 pounds. There are ball cocks made in which the buoyancy of the ball merely operates a small secondary valve in a way to establish the initial pressure over a disc of larger upper surface than that of the under side which covers the main water inlet of the cock. The disc is thus seated by the differential principle regardless of the pressure; and a 4-inch ball will close almost any size valve against any pressure.

When the cock is attached through the bottom of the tank, no precaution against sound is necessary. When the cock is fitted in high up, a pipe from the delivery is extended to near the bottom of tank for the purpose of muffling the sound of the water as it fills the tank. An unmuffled delivery and a high-tank flush make considerable noise when the closet is flushed, and are suggestive and very embarrassing to sensitive people. Silent action is therefore the goal for which many strive. Silence at the expense of thoroughly washing the closet surfaces and flushing out of the contents, is not desirable; some noise is necessary to the rapidity of action essential to thorough scouring and evacuation.

Tanks requiring the flush valve to be held off the seat during the entire flush, are now no longer installed. Perfect silence in the flush pipe of a high-tank closet has been obtained by a type of flush fittings that permits the pipe to hang full of water. The flush valve being opened, water begins to flow into the closet immediately. When the valve closes, no air having access at the upper end of the flush, the pipe remains filled. The flush valve of such a closet must close absolutely water-tight to prevent continual dribbling into the bowl.

Of late years, direct-flushing valves of many forms have been a feature of water-closet design. These valves make the individual closet tank unnecessary. Direct-flushing closets, a type of which is shown in Fig. 44, have the same advantage as the low tank in the matter of being placed where high closets cannot conveniently be arranged. A check to their more general adoption has been the lack of large supplies in residences and other buildings.

The possibility that the house system of water supply may be contaminated from the water-closet if the water supply is directly connected to the water-closet fixture, should not be overlooked. Although this contamination is more likely to take place in the operation of the older types of closets, such as the pan closet and the plunger type, it is not of rare occurrence in connection with later types, especially the so-called *frost-proof* fixture. If the pressure is materially lowered in the street main by accident or otherwise, it sometimes happens that water may be drawn back into the house system by siphonage from a water-closet or like fixture, thus of course incurring the possibility that germs of disease may be brought into the water supply used for domestic purposes. The use of a tank into which the water is first drawn, obviates this danger.

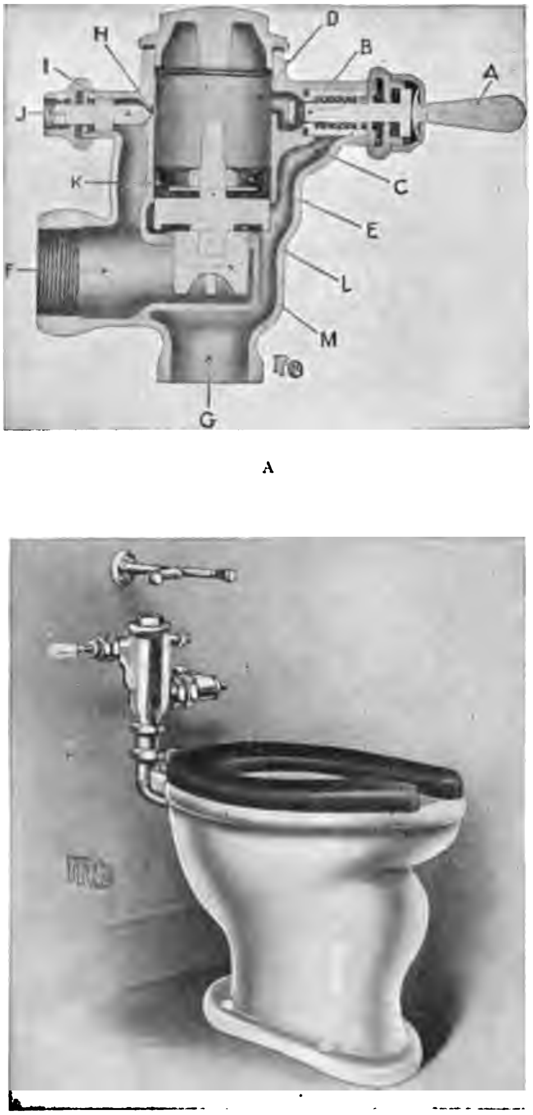
A dwelling or storehouse supply will operate direct flushing valves successfully by placing an accumulating chamber on the branch to the closet, and having a check-valve on the street side of it, so that the water cannot flow back when the pressure falls as a result of drawing at other points. In such cases the pipe between the accumulator and the closet must be the usual $1\frac{1}{2}$-inch size. Closets thus fitted are really only pressure-tank closets with the flush controlled by a direct-flushing valve to be operated at will instead of automatically by seat-action.

In all tank installations, the direct method is easily employed by carrying the proper size flush main directly to the closets, independently of the supply for other fixtures. This is recommended in buildings having numerous closets. One tank, with large flushing main, will serve all the closets, and thus the individual tanks and equipment are not needed. Furthermore, no trouble is then experienced in providing suitable space for the small tanks. The flushing valves may, if desired, be placed out of sight, and only the operating lever brought to view in a convenient position. A flushing valve has been made which, like the secondary-valve ball cock, works on the old Jennings diaphragm principle, using a "time" filling cup to establish the initial pressure over the diaphragm. Releasing the pressure over the diaphragm by means of the operating lever, opens the main channel and causes the closet to flush while the time chamber fills again.

In this country and most others, the height of closets has always been uniformly 16 to 17 inches to top of seat. It is claimed that this height results in an unnatural position, and individual opinions against it have been voiced from time to time with little effect. Lately, however, more earnest attention has been given the subject of height, and there has been designed a closet considerably lower than usual, with the top sloping down toward the back. This form, it is said, induces the user to assume an upright position of body, relatively more closely conforming to that of the limbs, and favoring unrestricted action of the intestines. It remains to be seen whether this form will result in any general departure from the old lines.

Closets often also serve as urinals, especially in private houses. For limited service, this is not to be considered an actual abuse of the fixture, though general use of distinct urinal fixtures is indispensable.

Range Closets. Batteries of individual closets are usual in office buildings and many other such structures; but in schools and in many public places open to all classes, ranges divided into stalls or compartments have been considered a satisfactory solution of the problem.



A

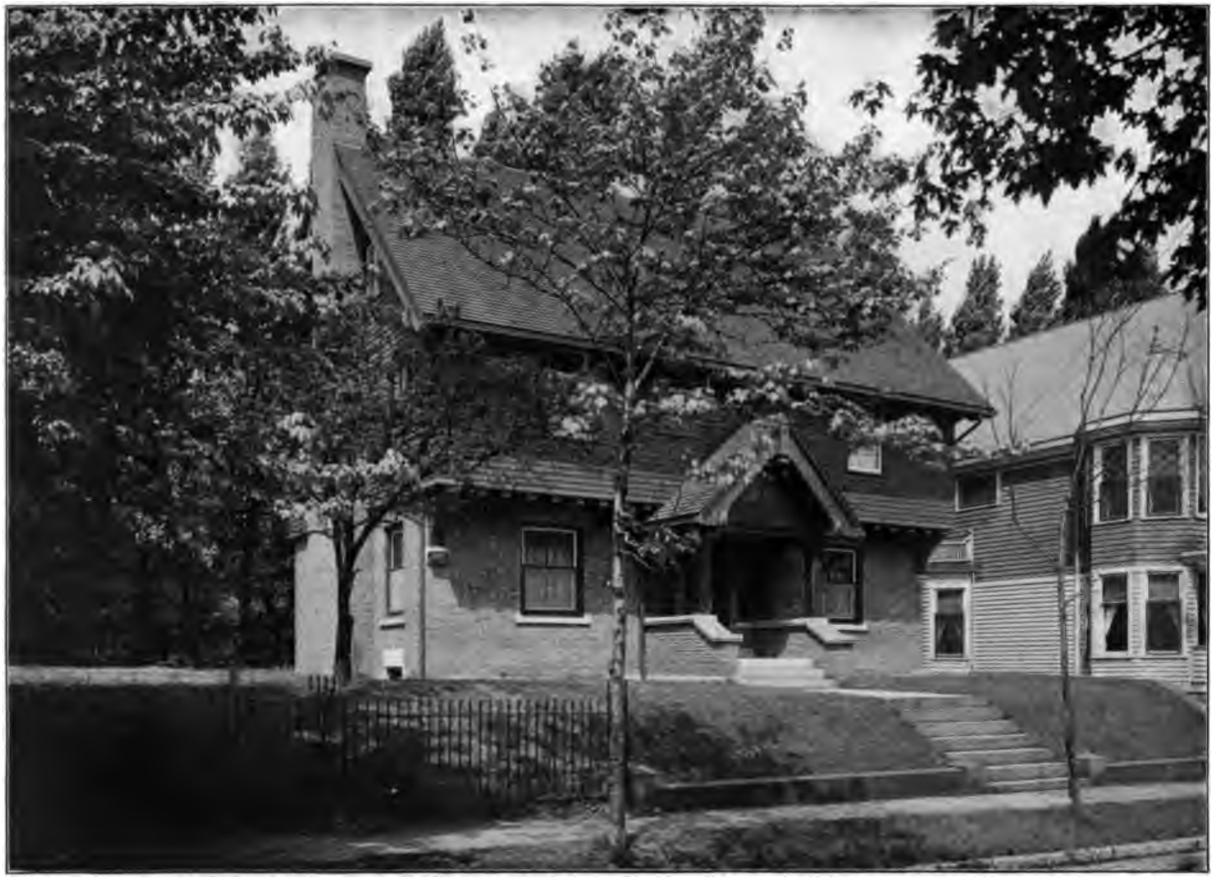
B

Fig. 44. Direct-Flushing Closet
Flushing Valve Shown in Section above
Courtesy of Federal-Huber Company, Chicago

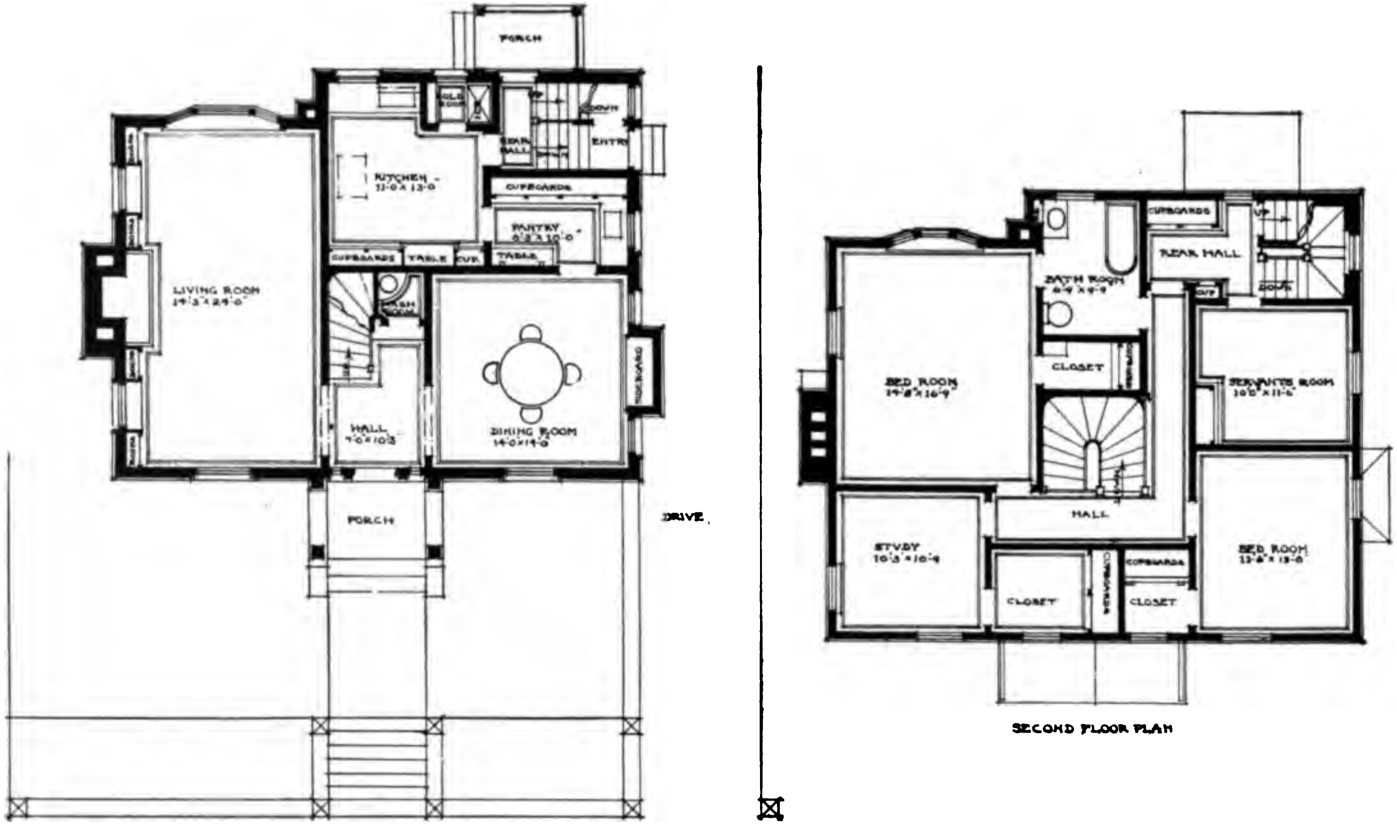
The objections to the range type of fixture are inherent in the design. The fouling surface of a trough fixture is much greater than that of the number of individual closets to which the fixture corresponds, and certain parts of this surface are not subject to an adequate flushing action. A certain portion of the surface, much larger relatively than that in individual fixtures, is exposed to spattering with the filth, and is alternately wet and dry. It is also true that the method of applying the water for scouring purposes is much less satisfactory than with single closets. A further objection to the range fixture is that in general its material is less desirable for the purpose than the earthenware or porcelain used for closets. On account of these deficiencies, for some ten years past, individual closets have been used in public schools in certain cities which have given the most attention to this branch of sanitation, and their use is being extended.

Range closets have automatic flushing tanks acting at any required interval between flushes. The tanks are, as a rule, without moving parts, and give good service without much attention after the supply is once set to flush at the interval desired. Whether the users of a closet are indifferent or irresponsible, does not change the result of abuse; and the range type of closet overcomes many annoyances attending the use of ordinary individual closets in unsuitable places—institutions for the insane and feeble-minded, for example. Ranges, like seat-action closets, are not dependent on the user, who may forget to pull a chain or push a button and thereby leave the closet foul.

Various forms of ranges are now operated on the siphon eduction principle. Siphonic eduction is accomplished in three ways—first, by the double trap and air-pipe to the tank indicated by the sectional view, Fig. 45, and operating exactly like the individual pneumatic closet already described; second, by a siphon outlet-end in which the water falls over a central weir that maintains the proper depth of water until the flush begins, and causes siphonage by breaking up and filling the channel as it passes through a constricted bend below. The latter method is shown in section in Fig. 46. Still another type of range is made to siphon by jet-action, just as the individual jet-siphon closet does, the trap providing a retaining weir which holds the water at the proper level in the range between flushes.



RESIDENCE OF MR. E. S. MEYER, CLEVELAND, OHIO
Watterson and Schneider, Architects, Cleveland, Ohio
First story of brick; second story and roof of shingles. Cost, $7000. For plans see opposite page.



•FIRST•FLOOR•PLAN•

SECOND FLOOR PLAN

FIRST AND SECOND STORY PLANS OF RESIDENCE OF MR. E. S. MEYER, CLEVELAND, OHIO

Watterson & Schneider, Architects, Cleveland, Ohio.

There are wash-out ranges with sloping weirs at the outlet to retain enough water to keep soil from sticking. These are open troughs, and the plumber provides the trap. Some siphon ranges are of the open-trough pattern, but the trap or the siphon outlet is a part of the fixture. All open-trough ranges can be supplied with a ventilating section from which a large vent pipe may be carried to a stack in which a draft is insured by a hot flue or some other means. Such ventilation changes the air in the room; and by having lids to all the seats, odors from the entire trough may be uniformly removed by leaving up one lid only, at the end opposite the vent pipe. Some forms, having individual flushing-rim bowls cast integral with the section, are supplied by one general flush pipe, as indicated by the plan and elevation shown in Fig. 47. In these, each bowl is separately water-sealed, as the normal water-level is above the general conduit into which the bowls discharge.

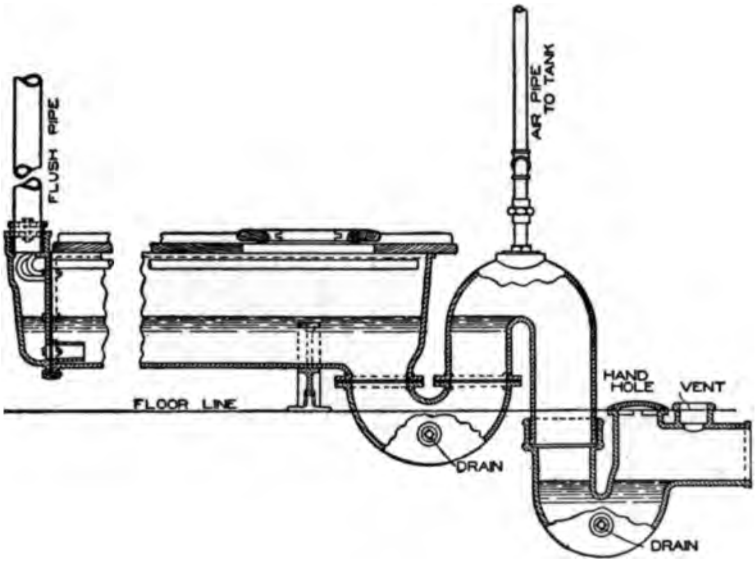


Fig. 45. Section of Range Closet, with Double Trap and with Air-Pipe to Tank to Cause Siphonic Eduction.

Other forms, which receive the entire flush at one end, are water-sealed between the seat holes. The seat-openings, instead of converging like flushing-rim bowls, diverge downward, so that, as the water-level recedes in the sections during flushing, soil falls away from the surface by gravity instead of grinding against it. Therefore, so far as cleanliness is concerned, the type with diverging surfaces but without the scouring effect of flowing water in the openings is, in operation, the practical equivalent of the flushing-rim type with converging surfaces. The open-trough ranges, including the jet-siphon type, have perforated wash-down pipes along the sides and ends, which, however, have little value. The open troughs are made in cast sections as long as convenient, joined by flanges with rubber gaskets and bolts. Suitable feet or chairs for supports are furnished with these fixtures.

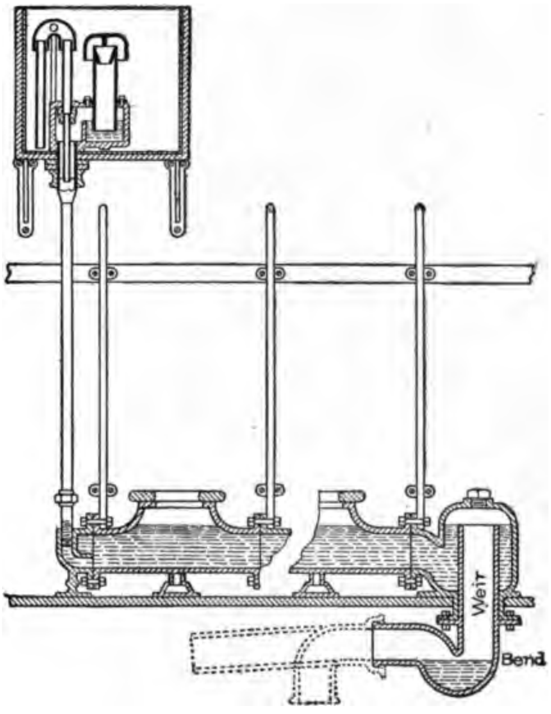


Fig. 46. Section of Range Closet, with Siphon-Outlet End.

Cast partitions, partitions and backs, and full compartment partitions, with slat doors and indicators, are furnished to order in any style or combination desired. For example, the range for a schoolroom may consist altogether of 24-inch sections or divisions, except one intended for the teachers' use made 30 inches and fitted with door and full-length partitions to give a thoroughly private compartment. Ranges are usually made of cast iron, and almost invariably finished with enameled interior and painted exterior. Bowl or section ventilation is provided for where possible. Wood seats and covers are generally used; but enameled-iron top frames with hinged seats and covers, and rigid enameled seats, are also made.

The lower trap of a double-trap range must be ventilated. All soil-pipe stacks into which ranges discharge, and fixtures connected to them, must be well protected against siphonage, because the volume of water discharged at one time by a range is sufficient to siphon traps that ordinarily would retain their seals.

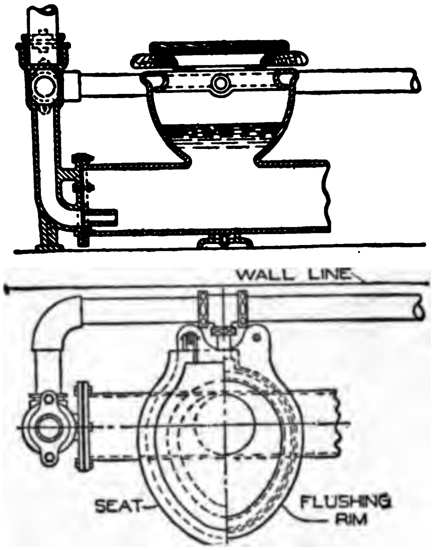


Fig. 47. Sectional Elevation and Plan of Range Closet Seat with Flushing-Rim Bowl Supplied from General Flush-Pipe

Urinals. Sectional urinals are made of the same materials and finish, and with much the same types of design, as range closets. They are generally installed in the same classes of buildings as range closets; but such urinals will often be found in the same toilet-room with individual closets. Roll-rim enameled troughs, with back and with simple perforated wash-down flush pipes on the back, are available. Solid porcelain stalls, are also in the market.

Single urinals are usually of porcelain, although some have been made of iron. Pedestal flushing rim urinals, resembling an extra tall water-closet bowl, are now regular market fixtures. The common types are plain or lipped, Fig. 48, made in flat-back and corner

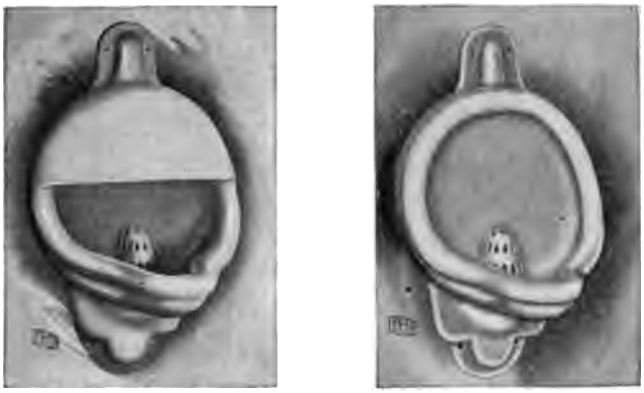


Fig. 48. Standard Types of Vitreous China Urinals
Courtesy of Federal-Huber Company, Chicago

designs. Direct-flushing valves of the same type as used on closets, adapted to the purpose, and cocks of various types, are the means of flushing generally provided for a single urinal. When two or more are placed in one toilet-room, an automatic tank with branched flush pipe is employed. These tanks are of greater variety than those used with range closets. The tilting bucket, pivoted within a tank case, which empties itself periodically by means of the flow of water changing the center of gravity to the unsupported side and tipping it just before it overflows, is a familiar type of automatic urinal-flushing tank. The standard tank with immovable parts, which siphons automatically, is the most prevalent. A section showing the "Watrous" automatic tank valve is given in Fig. 49.

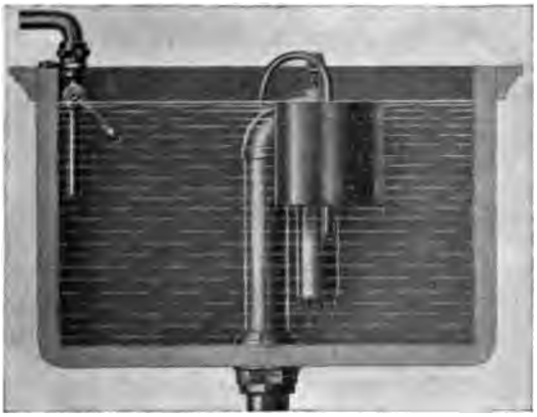


Fig. 49. "Watrous" Automatic Tank Valve
Courtesy of Federal-Huber Company, Chicago

Another design consists of a tank with common siphon, fitted with a ball cock which *opens*, instead of closing, as the water in the tank lifts the ball. The interval between flushes is governed by a small bibb cock. When water lifts the ball, the ball cock also admits water, the tank filling.

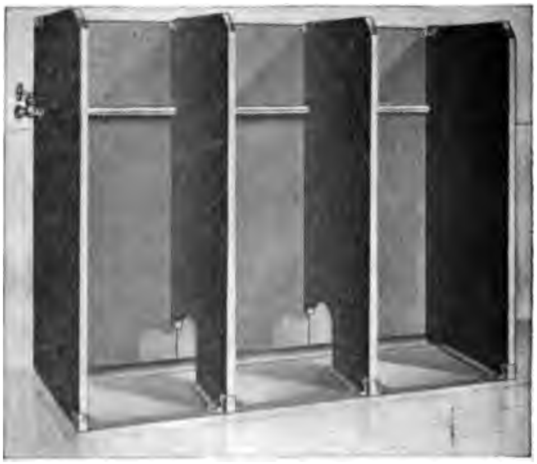


Fig. 50. Urinal Stalls of Slate, Flushed by Perforated Pipe, with Guttered Floor
Courtesy of Federal-Huber Company, Chicago

rapidly. The higher the ball is lifted, the faster the tank fills, so that by the time the water-level reaches a point where water begins to flow over the neck of the siphon, it is coming into the tank rapidly enough to more than keep pace with the overflow necessary to start the siphon. True siphonage, however, empties the tank much faster than the supply can fill it; and the tank is soon empty, leaving the small bibb cock to admit water again slowly to where this action can be repeated.

Individual urinals which siphon by admitting additional water to that which normally stands in the fixture, and various other types, will be best understood from a study of dealers' catalogues. In good work, marble backs and partitions usually enclose the urinals on three sides. Marble and slate stalls of various construction, with channeled and guttered floor, as shown in Fig. 50, all washed by perforated pipes fixed along the surfaces, are frequently used in lieu of specific urinal fixtures. A thick base of slab material is sometimes used, the gutter and drain-hole being cut in it. Cast-iron gutters, galvanized or enameled, with an outlet-end adapted to a soil-pipe connection, are supplied by the makers.

In describing the fixtures and trimmings that have been noticed, only salient features of form and principles of design have been considered. Sufficient guidance to insure intelligent comparison of merits and skilful discrimination in selection, has been given. Catalogue detail and illustration, and a view of the actual goods described therein, should, with what has now been given, insure the fullest understanding of the fixture branch of Plumbing.

HOUSE WATER SUPPLY

While the plumber is apt to give more attention to supply pipe, and to methods of installing it in buildings to secure specific service, *water supply* embraces also, in its broadest sense, the source and quality of water and the means of conveying it to the building. Plumbers generally have little dealing with water supply outside of the house walls. Custom has fixed certain arbitrary sizes in ordinary work, to such a degree that the average plumber has generally ignored information on the flow of water through pipes. Indeed, he is so rarely in actual need of this knowledge, that it appears a burden to acquire and to fix permanently in his mind the simplest formula bearing on the subject. Enough information to determine approximate deliveries and point the road to further research, will not be out of place in behalf of those who may need simple directions.

The laws of gravity are the basis for the science of hydraulics, of which a prime factor of every problem is *velocity.* There is no exception to the rule that all bodies falling freely, descend at the same rate—in round numbers, 16 feet for the first second, at the end of which the acquired velocity is one of 32 feet a second. This is the basis on which are formulated the laws of falling bodies, which, exhibiting what is known as *velocity of efflux,* together with loss by friction, must be considered when calculating the flow of water.

There are three kinds of velocity—*uniform, accelerated,* and *retarded.* It is the last, and its cause, friction, that plumbers should be most interested in, as velocities calculated merely from the laws of falling bodies do not take account of friction, change of course, etc., which must be allowed for as causes diminishing the delivery of water through pipes. Briefly stated, the mysterious-looking Torricellian formula $\sqrt{2gh} = V$, means only that velocity is found by extracting the square root of the product of the head multiplied by 2 × 32, g standing for the force of gravity, and h for the height. For example, a stream filling a 1-inch pipe, with 25 feet head of water, would have a velocity calculated thus: $2 \times 32 \times 25 = 1{,}600$; and the square root of $1{,}600 = 40 =$ Velocity, friction not considered.

The shape of the orifice through which water enters a pipe, has much to do with the amount of water that will enter it. Friction against the sides of the pipe, and change of direction due to bends and connections, occasion great variation from the theoretical flow. Not only is the character of the pipe surface and fittings to be considered as initial causes varying the delivery, but velocity, the all-important factor, must be reckoned with in every instance. With a velocity of 10 feet per second in a pipe of comparatively smooth interior surface, the friction loss in pounds on one square foot of surface will be about ½ pound. If this velocity is increased or diminished, the factor of friction will vary accordingly, always in proportion to the square of the velocity. Suppose the velocity to be 20 feet instead of 10 feet per second; we then have, 10 squared equals 100, and 20 squared equals 400. The square of these velocities is as 1 to 4, and as we assign a ½-pound loss to ten feet velocity per second, on a stated amount of surface, the friction due to doubling the velocity should be four times a ½ pound = 2 pounds, showing that doubling the velocity increases the friction four-fold; trebling it increases friction nine-fold, etc.

A column of water weighs .43 pound per square inch of base, per vertical foot. Therefore a vertical pipe 100 feet high, with 1-inch sectional area, filled with water, would contain 43 pounds, and a gauge at the bottom would show 43 pounds pressure. If the pipe were only ¼ inch, or were 40 inches in diameter, the gauge would show the same pressure for the same vertical height—namely, .43 pound per square inch per vertical foot. A head of water expressed in feet, may be changed to pounds by multiplying the feet of head by .43. Pressure is made to read in feet of head by multiplying pressure per square inch by 2.3. A *head of water* is the number of vertical feet from level of source of supply to center of outlet or point of delivery.

Diameter of the pipe has nothing to do with static head or pressure; but its relation to the size of the orifice from which the water is to be drawn has much to do with the amount of pressure lost by friction. If a faucet and supply pipe are of equal capacity, and we *double* the size of the pipe, the velocity of the water flowing through it is reduced three-fourths; and the friction is, under these conditions, but one-sixteenth what it was in the original size. Moreover, as in drawing similar amounts of water under the same head through a one-inch and a two-inch pipe, the amount of friction surface presented is twice as great in the one-inch as in the two-inch pipe, the friction in the one-inch can be shown to be 32 times as much as in the two-inch pipe.

With the formula given above, one can roughly approximate by finding the theoretical delivery and deducting a liberal percentage for friction, according to size, length of pipe, and head or pressure. The subject, however, is vast and tedious, introducing intricate calculations in higher mathematics when considered in detail with a view to extreme accuracy of results, and is a branch properly belonging to hydrodynamics, rather than suited to presentation at length here. Two tables are given, however, which with the rules for use, will be of value to those who fail to make further research.

Table I shows the pressure of water in pounds per square inch for elevations varying in height from 1 to 135 feet.

Table II gives the drop in pressure due to friction in pipes of different diameters for varying rates of flow. The figures given

TABLE I

Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch
1	.43	46	19.92	91	39.42
2	.86	47	20.35	92	39.85
3	1.30	48	20.79	93	40.28
4	1.73	49	21.22	94	40.72
5	2.16	50	21.65	95	41.15
6	2.59	51	22.09	96	41.58
7	3.03	52	22.52	97	42.01
8	3.46	53	22.95	98	42.45
9	3.89	54	23.39	99	42.88
10	4.33	55	23.82	100	43.31
11	4.76	56	24.26	101	43.75
12	5.20	57	24.69	102	44.18
13	5.63	58	25.12	103	44.61
14	6.06	59	25.55	104	45.05
15	6.49	60	25.99	105	45.48
16	6.92	61	26.42	106	45.91
17	7.36	62	26.85	107	46.34
18	7.79	63	27.29	108	46.78
19	8.22	64	27.72	109	47.21
20	8.66	65	28.15	110	47.64
21	9.09	66	28.58	111	48.08
22	9.53	67	29.02	112	48.51
23	9.96	68	29.45	113	48.94
24	10.39	69	29.88	114	49.38
25	10.82	70	30.32	115	49.81
26	11.26	71	30.75	116	50.24
27	11.69	72	31.18	117	50.68
28	12.12	73	31.62	118	51.11
29	12.55	74	32.05	119	51.54
30	12.99	75	32.48	120	51.98
31	13.42	76	32.92	121	52.41
32	13.86	77	33.35	122	52.84
33	14.29	78	33.78	123	53.28
34	14.72	79	34.21	124	53.71
35	15.16	80	34.65	125	54.15
36	15.59	81	35.08	126	54.58
37	16.02	82	35.52	127	55.01
38	16.45	83	35.95	128	55.44
39	16.89	84	36.39	129	55.88
40	17.32	85	36.82	130	56.31
41	17.75	86	37.25	131	56.74
42	18.19	87	37.68	132	57.18
43	18.62	88	38.12	133	57.61
44	19.05	89	38.55	134	58.04
45	19.49	90	38.98	135	58.48

are for pipes 100 feet in height. The frictional resistance in smooth pipes having a constant flow of water through them is proportional to the length of pipe. That is, if the friction causes a drop in pressure of 4.07 pounds per square inch in a 1¼-inch pipe 100 feet long, which is discharging 20 gallons per minute, it will cause a drop of $4.07 \times 2 = 8.14$ pounds in a pipe 200 feet long; or $4.07 \div 2 = 2.03$ pounds in a pipe 50 feet long, acting under the same conditions. The factors given in the table are for pipes of smooth interior, like lead, brass, or wrought iron.

TABLE II

Friction Loss in lb. per sq. in., per 100 ft. of Clean Iron Pipe of Sizes Given, Together with Number Gallons Discharged per min., and Velocity of Flow of Water per sec.

Gallons Discharged (per min.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Gals. Discharged (per min.)
	½-in. Pipe		¾-in. Pipe		1-in. Pipe		1¼-in. Pipe		1½-in. Pipe		2-in. Pipe		
5	8.17	24.6	3.63	3.3	2.04	0.84	1.31	0.31	0.91	0.12	....	....	5
10	16.30	96.0	7.25	13.0	4.08	3.16	2.61	1.05	1.82	0.47	1.02	0.12	10
15	....	....	10.90	28.7	6.13	6.98	3.92	2.38	2.73	0.97	....	....	15
20	....	....	14.50	50.4	8.17	12.3	5.22	4.07	3.63	1.66	2.04	0.42	20
25	....	....	18.10	78.0	10.20	19.0	6.53	6.40	4.54	2.62	....	....	25
30	....	....	....	....	12.30	27.50	7.84	9.15	5.45	3.75	3.06	0.91	30
35	....	....	....	....	14.30	37.0	9.14	12.40	6.36	5.05	....	....	35
40	....	....	....	....	16.30	48.0	10.40	16.10	7.26	6.52	4.09	1.60	40
45	....	....	....	....	....	....	11.70	20.20	8.17	8.15	....	....	45
50	....	....	....	....	....	....	13.10	24.90	9.08	10.00	5.11	2.44	50
75	....	....	....	....	....	....	19.60	56.10	13.60	22.40	7.66	5.32	75
100	....	....	....	....	....	....	....	....	18.20	39.00	10.20	9.46	100
125	....	....	....	....	....	....	....	....	....	....	12.80	14.90	125
150	....	....	....	....	....	....	....	....	....	....	15.30	21.20	150
175	....	....	....	....	....	....	....	....	....	....	17.10	28.10	175
200	....	....	....	....	....	....	....	....	....	....	20.40	37.50	200

	2½-in. Pipe		3-in. Pipe		4-in. Pipe		6-in. Pipe		8-in. Pipe		10-in. Pipe		
25	1.63	0.21	1.13	0.10	....	....	....	....	....	....	....	....	25
50	3.26	0.81	2.27	0.35	1.28	0.09	....	....	....	....	....	....	50
75	4.90	1.80	3.40	0.74	....	....	....	....	....	....	....	....	75
100	6.53	3.20	4.54	1.31	2.55	0.33	1.13	0.05	....	....	....	....	100
125	8.16	4.89	5.67	1.99	....	....	....	....	....	....	....	....	125
150	9.80	7.00	6.81	2.85	3.83	0.69	1.70	0.10	....	....	....	....	150
175	11.40	9.46	7.94	3.85	....	....	....	....	....	....	....	....	175
200	13.10	12.47	9.08	5.02	5.11	1.22	2.27	0.17	....	....	....	....	200
250	16.30	19.66	11.30	7.76	6.39	1.89	2.84	0.26	1.59	0.07	1.02	0.03	250
300	19.60	28.06	13.60	11.20	7.66	2.66	3.40	0.37	....	....	....	....	300
350	....	....	15.90	15.20	8.94	3.65	3.97	0.50	....	....	....	....	350
400	....	....	18.20	19.50	10.20	4.73	4.54	0.65	....	....	....	....	400
450	....	....	20.40	25.00	11.50	6.01	5.11	0.81	....	....	....	....	450
500	....	....	22.70	30.80	12.80	7.43	5.67	0.98	3.19	0.25	2.04	0.09	500
750	....	....	....	....	....	....	8.51	2.21	4.79	0.53	3.06	0.18	750
1000	....	....	....	....	....	....	11.30	3.88	6.38	0.94	4.08	0.32	1000
1250	....	....	....	....	....	....	....	....	7.97	1.46	5.10	0.49	1250
1500	....	....	....	....	....	....	....	....	9.57	2.09	6.12	0.70	1500
1750	....	....	....	....	....	....	....	....	....	....	7.15	0.95	1750
2000	....	....	....	....	....	....	....	....	....	....	8.17	1.23	2000

The friction due to fittings is generally taken to equal straight additional pipe for each as follows: 90° ells, 40 diameters; pipe entering tee, 60 diameters; pipe entering coupling, 20 diameters, and, interposing a globe valve, 60 diameters.

Examples. A 1½-inch pipe 100 feet long connected with a cistern is to discharge 35 gallons per minute. At what elevation above the end of the pipe must the surface of the water in the cistern be to produce this flow?

In Table II we find the friction loss for a 1½-inch pipe discharging 35 gallons per minute to be 5.05 pounds. In Table I we find a pressure of 5.2 pounds corresponds to a head of 12 feet, which is approximately the elevation required.

How many gallons will be discharged through a 2-inch pipe 100 feet long where the inlet is 22 feet above the outlet? In Table I we find a head of 22 feet corresponds to a pressure of 9.53 pounds. Then, looking in Table II, we find in the column of Friction Loss for a 2-inch pipe that a pressure of 9.46 corresponds to a discharge of 100 gallons per minute.

Tables I and II are commonly used together in examples.

A house requiring a maximum of 10 gallons of water per minute is to be supplied from a spring which is located 600 feet distant, and at an elevation of 50 feet above the point of discharge. What size of pipe will be required? From Table I we find an elevation or head of 50 feet will produce a pressure of 21.65 pounds per square inch. Then if the length of the pipe were only 100 feet, we should have a pressure of 21.65 pounds available to overcome the friction in the pipe, and could follow along the line corresponding to 10 gallons in Table II until we came to the friction loss corresponding most nearly to 21.65, and take the size of pipe corresponding. But as the length of the pipe is 600 feet, the friction loss will be six times that given in Table II for given sizes of pipe and rates of flow; hence we must divide 21.65 by 6 to obtain the available head to overcome friction, and look for this quantity in the table, $21.65 \div 6 = 3.61$, and Table II shows us that a 1-inch pipe will discharge 10 gallons per minute with a friction loss of 3.16 pounds, and this is the size we should use.

EXAMPLES FOR PRACTICE

1. What size pipe will discharge 40 gallons per minute, a distance of 50 feet, with a pressure head of 19 feet? Ans. 1¼-inch
2. What head will be required to discharge 100 gallons per minute through a 2½-inch pipe 700 feet long? Ans. 52 feet

In calculating the contents of pipes, cylinders, and cisterns, where it is usual to correct the area found as a result of squaring the diameter by multiplying by .7854, before dividing by 231 for U. S.

gallons, multiplication by the decimal may be omitted, and dividing by 294 instead of 231 will then give the same result.

TYPES OF WATER SUPPLY

There are various ways in which it may be necessary to obtain the water supply for a building. The usual course in cities and towns is to employ the Municipal Water Works service. This, of course, settles the supply feature, and the plumber simply provides the house and yard pipe, ⅝-inch or larger main, according to the character of the work. If of lead, the pipe must be of strength according with the pressure. Any of the light-weight grades of lead supply will stand 1,000 pounds per square inch for a short time; and the usual strength used on 50- to 80-pound pressure will not burst under 1,400 to 1,600 pounds when new and unstrained. Under constant pressure, the enormous strain possible from water-hammer, and general deterioration from use, make it advisable to employ pipe which, when new, is 20 times as strong as that necessary to contain the pressure. No attention is necessary as to the strength of zinc-coated or tin-coated iron pipe; it will stand any pressure ordinarily encountered.

The two general methods of supplying buildings with water are: (1) the *direct* system; and (2) the *indirect* or *tank* system. The direct method, generally employed in cities, places each fixture connected with the supply under the same pressure as the street main, unless a reducing valve is introduced, thus often subjecting the work to needless high pressure and always to the widely varying conditions and quality of service incidental to such use. In the direct system it is good practice, where at all practicable, to pipe and fit the work generally for pressure not exceeding 50 pounds per square inch, and then use a reducing valve to maintain such pressure as is required.

The indirect method is almost always necessarily employed in isolated work; and even where municipal service is available, it is generally better for ordinary domestic purposes. With the indirect system, the connection with the street main is carried directly to a tank placed in the attic, or at some point above the highest fixture, as shown in Fig. 51. The supply to tank is regulated by a ball-cock which automatically shuts off the water when the tank becomes full, and opens and refills it again when water is drawn out. All the plumbing fixtures are supplied directly from the tank, and are therefore under a constant minimum pressure depending on the distance the fixtures are situated below the tank. The tank storage is a matter of great convenience during repairs to street mains, aside from its advantages of uniform pressure, reduced expense of fitting and maintaining low-pressure work, etc.

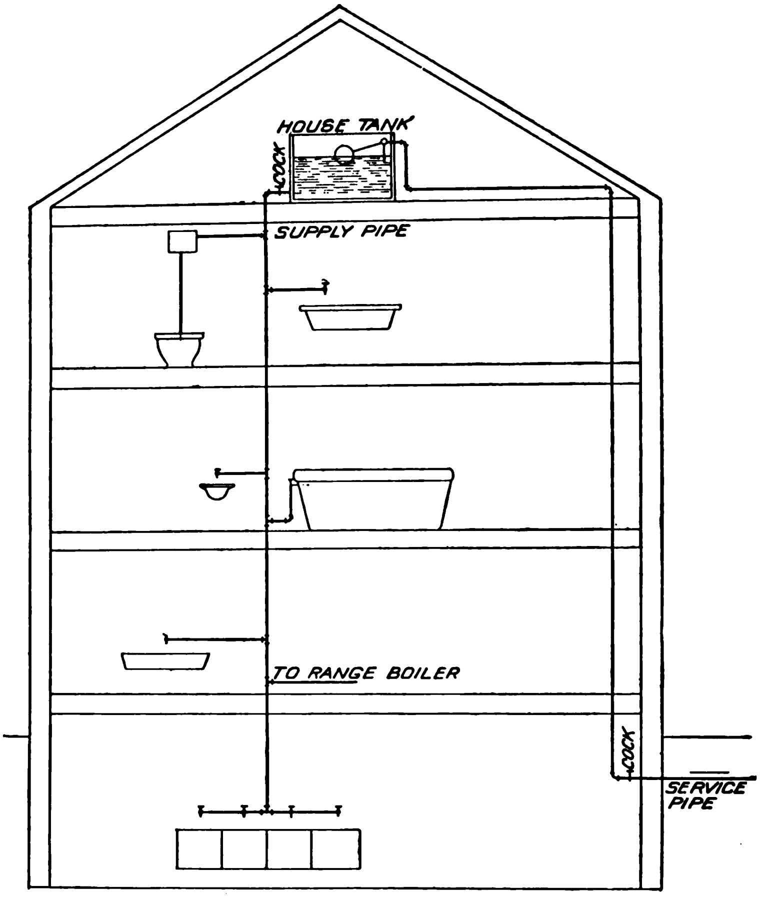


Fig. 51. Indirect or Tank System of House Supply.

In municipalities where the pressure in the main is not sufficient to carry the water up to the house tank in the attic, and in elevated situations, an automatic, electrically-operated rotary or other suitable form of pump is often installed to lift the water. A screw pump like that shown in Fig. 52 is especially adapted to this use when equipped with an electric motor to start and stop automatically by means of a float in the tank operating an electric switch as shown in the engraving.

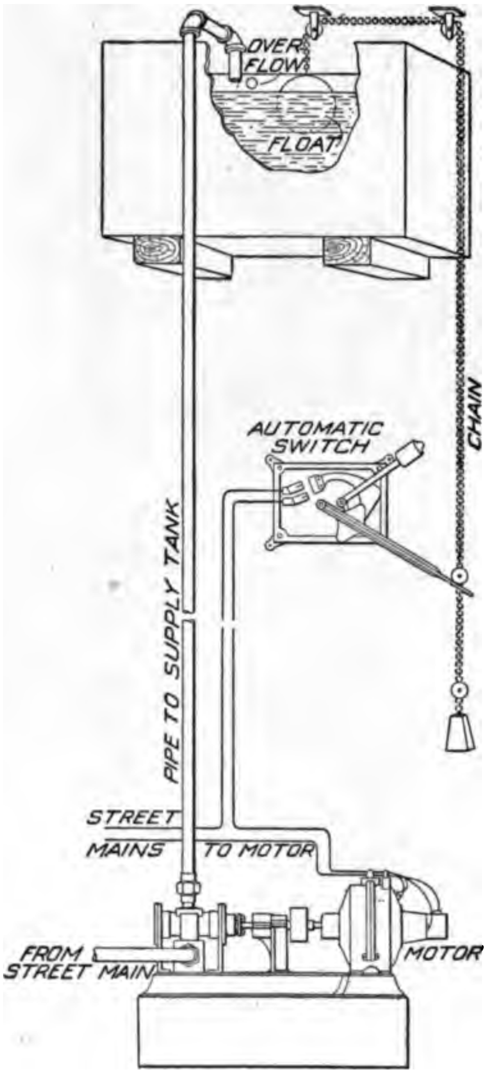


Fig. 52. Electrically-Operated Pump for Lifting Water to Tank. Automatically Started and Stopped by Means of Float Operating Electric Switch.

Where steam pressure is available, steam-operated pumps are very frequently used, and are invariably arranged for automatic service whether there are engineers regularly in attendance or not. A device that may be attached to steam pumps for this purpose is shown in Fig. 53. When the high-water line in the tank is reached, the float closes a valve in the pump discharge pipe, thus promptly increasing the pressure in it so as to actuate a piston through a pipe connection from the pump discharge to the regulator beneath the piston head. The regulator is shown complete, in detail, partly in section, in Fig. 54. Raising the piston shuts off the steam supply to the pump at the governor valve. When the water line in the tank is lowered, the float falls and the ball valve opens, relieving the pressure in the pump discharge pipe and allowing the steam governor valve to open by the action of the coun-

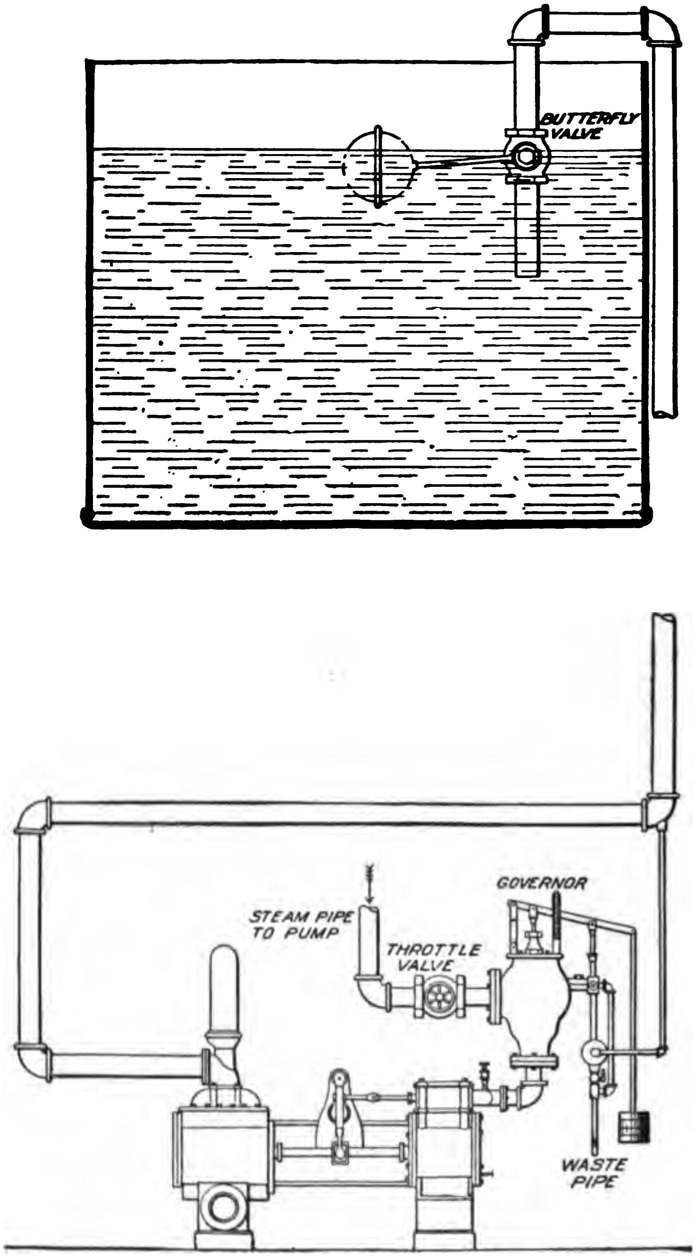


Fig. 53. Steam Pump Equipped with Regulator Operated by Float in Tank, Securing Automatic Service.

terweights attached to the lever arm, as shown; and the pump then works regularly until the lifting of the float by the rising water again closes the valve in the pump discharge and repeats the action described.

Outside of corporations, the supply may be from an elevated spring or stream, or from wells, cisterns, or other sources below the level of use. If the natural supply is high enough, it may be conveyed into a tank of sufficient height without intermediate apparatus. Tanks inside the dwelling or house are best, ordinarily.

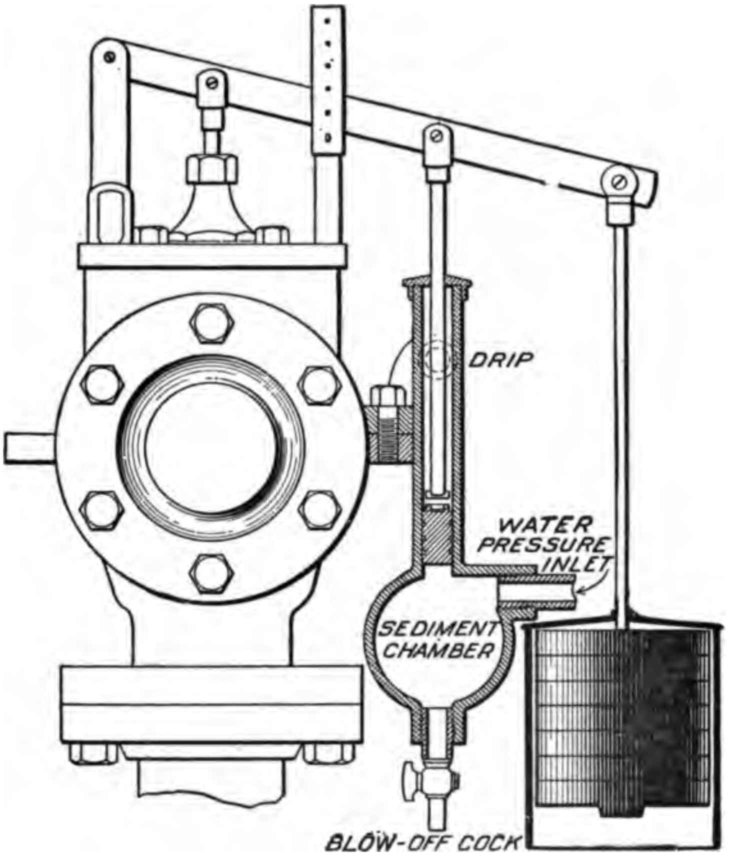


Fig. 54. Steam Pump Regulator (Shown Partly in Section) Automatically Operated by Valve Controlled by Float in Supply Tank.

Tanks for cold-water storage are made of various materials and in different shapes and sizes, according to the special uses for which they are required. For indoor use, copper-lined or lead-lined wood-case tanks without safe-pans, and wrought-iron or cast-iron tanks with safe-pans to catch the condensation, constitute the list generally favored by reason of superior fitness. Within limited dimensions, a durable and satisfactory tank-case can be made of heavy, well-fitted, and well-seasoned plank bolted together with iron rods and nuts, as shown in Fig. 55. For large sizes, heavy wood stays with tie-rods one-third of the way from each end, are added. With copper linings, but few nails should be used; and they should be so placed as to be covered by the copper, the joints being soldered by soaking the best quality of solder into the seams. The locking of the seams is shown greatly exaggerated in the engraving.

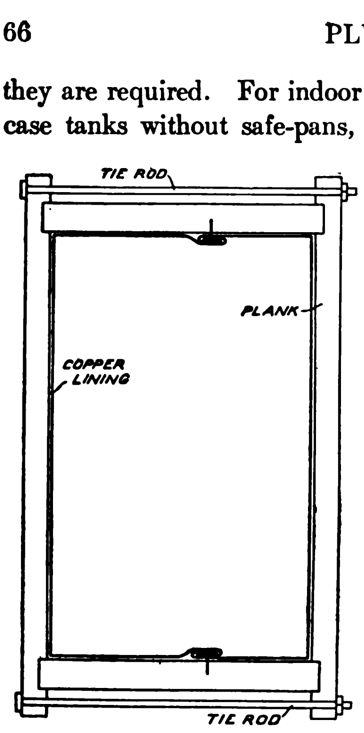


Fig. 55. Plan of Storage Tank in Case Made of Planks Bolted Together.

Cast-iron sectional tanks, like the form shown in Fig. 56, can be had in almost any size or shape. They are made up of plates planed

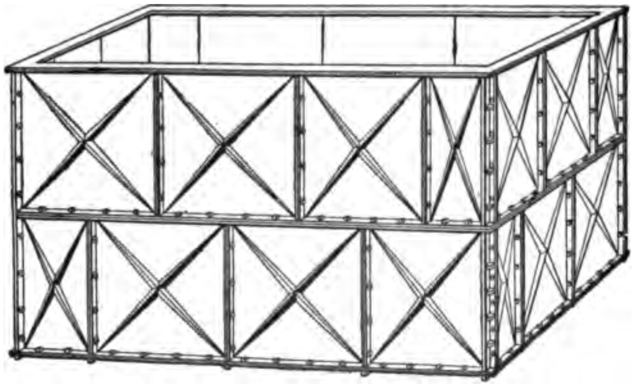
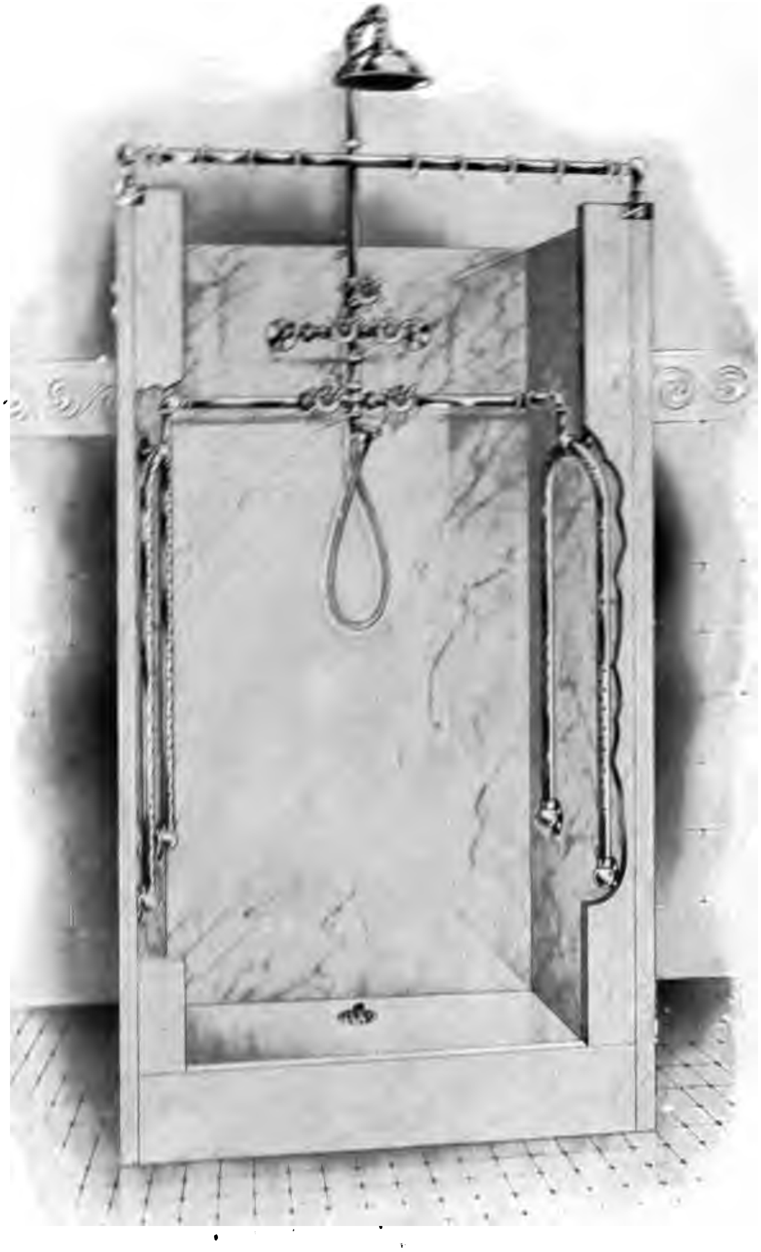


Fig. 56. Cast-Iron Sectional Tank.

and bolted together, the joints being made water-tight with cement. The sections are in convenient sizes, so that they can be handled



NICKEL-PLATED BRASS SHOWER BATH WITH SLATE CABINET
Courtesy of Federal-Huber Company, Chicago

easily, and conveyed without difficulty through small doorways or other openings to any part of the house. These tanks are easily set up, and are practically indestructible. Open and closed wrought-iron tanks, plain or galvanized, are often used, but are not so easily handled; and the larger sizes require to be riveted together and calked in place.

Lead-lined tanks are most frequently used for ordinary house plumbing. The linings were formerly wiped-in without exception. Sweating the lead together with a torch flame is however, quite as durable, and is much cheaper. To *sweat-in* a lining, take the exact length and breadth of the tank, trying at different points to be sure of allowing for any variations. Then cut out the bottom lining just the shape of the tank bottom, one and one-half inches larger each way, less twice the thickness of the lead. This allows three-quarters of an inch to turn up all around; and the bottom will just fit when the side pieces are in place. Mark off the bottom all around, as shown by the dotted lines in Fig. 57; and turn up the edge. With the intersection of the lines *A* as a center, and the termination of one of them as a starting point, describe the line *B*, and cut off the corner outside of it. Then *work* the corner up square without a kink. If the lead is heavy, a little heat will make it work better. After working-up, the lead at the corners will be much thicker than along the sides; this may be needed in stretching out, at some of the corners.

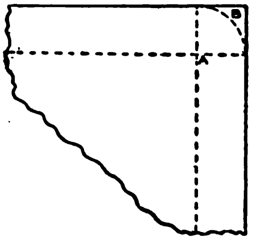


Fig. 57. Marking Off Bottom Sheet of Lead for Tank Lining. Leaving Edge to be Turned Up.

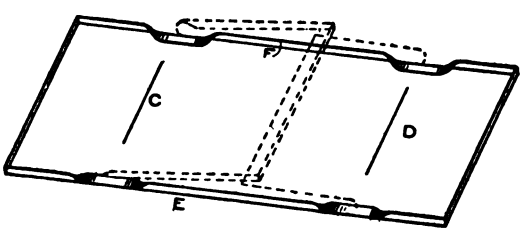


Fig. 58. Bending Bottom Sheet of Lead Ready to be Put in Tank.

When the edges and corners of the bottom are formed, clean the edges and about three-eighths of an inch down the outside all around, and rub the clean part with sperm candle. Next make a mark, say three feet from one end on each side, as at *E* and *F*, Fig 58. Then, on lines *C* and *D*, push the edges down inside, and fold the ends over as indicated by the dotted lines.

The bottom is now ready to be put in the tank, but it must wait until the sides and ends are in. If the sides and ends are light enough to be handled after joining like a ring, cut out a strip half an inch longer than will exactly go around the tank inside, equal to its depth plus the thickness of the tank wood for a flange at the top, as shown at J, Fig. 63. Then clean a half-inch of the under side and edge of the end that is to show in the seam, and three-quarters of an inch of the side that comes in contact with it, at the other end. The lead may then be propped up in the position shown in Fig. 59, by means of trestles and poles or in any other convenient manner; and the seam may be set, as shown, upon a board of hardwood, and the solder sweated into the lap by means of the torch and blowpipe. Solder for this kind of work should be three-fifths tin and two-fifths lead. A hardwood board is used because it will not smoke and burn like soft wood.

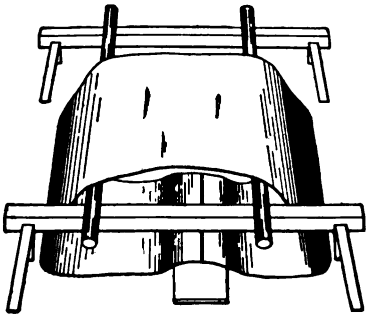


Fig. 59. Side and End Sheet of Lead Propped Up to Enable Seam to be Set and Soldered.

When the seam is made in this way, it shows inside the tank, and a good joint where the bottom seam crosses it can be made with ease, while one is never quite sure of the result if the seam crossed is on the other side.

Another method is to cut the lead the exact length that will go around the tank, clean the edges, butt them together over a hardwood board, as shown in Fig. 60, and *burn* them together instead of soldering. This can be done by using, instead of solder, a well-cleaned strip of lead about half an inch wide. Sperm candle will also answer as flux for burning. A piece of steel

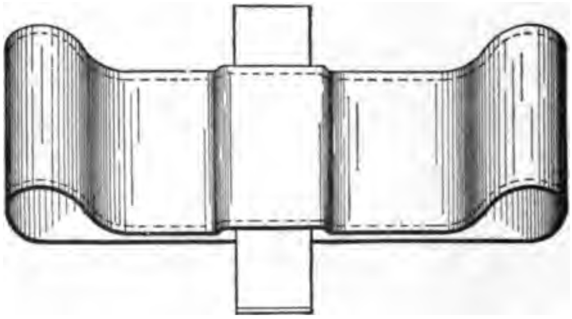


Fig. 60. Another Method of Joining the Two Ends of the Lead Sheet. The Ends are Butted against Each other Over the Hardwood Board and Fused Together.

or iron is best to place under the seam when burning, as more heat is required to do the work. An old crosscut saw blade, fastened to a board, serves well for such seams. The bottom edge of the side lining should be cleaned 1½-inches wide, as shown at *H*, Fig. 61, which indicates how the cleanings on the bottom and the side and end lining come together in the tank. It is a good plan to run the soil brush around the bottom edge of the lining, as shown at *O* and *P*, Fig. 61. The soil keeps the solder from sweating too deep, and enables the seam to fill quickly. Further than this, however, soiling, as in the preparation for wiping, is not necessary for sweated seams.

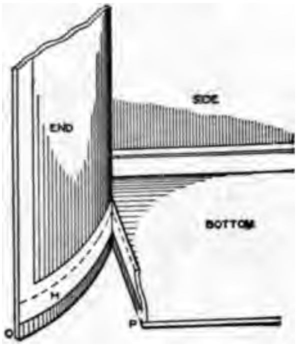


Fig. 61. Method of Joining End and Side Linings to Bottom Lining.

When the side lining "loop" is ready, lift it into the tank, square it out, flange over at the top, and secure the flange with brass, copper, or galvanized nails. Next, mark distances in the tank corresponding to those at *E* and *F* in Fig. 58. Then catch the bottom at the folded edges (Fig. 58), and lower it into the tank. As the ends are folded, there is room to stand inside the tank at the ends. Pull the folds upright so that marks *E* and *F* can be seen, and slide the bottom back or forward until *E* and *F* correspond with the marks made on the side lining. The ends may then be pushed down in place, and will be found to fit exactly if the measures have been properly taken.

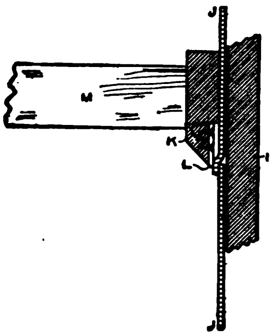


Fig. 62. Method of Keeping Lead in Place While Making Upright Seam in Tank.

After dressing down the bottom and pressing the turned-up edges against the sides and ends, sweat the bottom to the sides in the same way as the other seam was made, being sure that the solder "takes" well to both pieces of lead.

When a tank is large, handle the sides and ends in two or more pieces, always having the seams that are to be made in place come at the ends of the tank, as the ends are stiffest and best to brace against.

Fig. 62 shows the method of keeping the lead in place while making the upright seam in the tank, *I* being the tank wood, *JJ* the lining, *K* the straight edge, and *M* the brace. *K* is a piece of hardwood fastened to a strip of steel (a piece of an old framing square), as shown in the cut, the wood being about four inches wide by two feet long, and the steel *L* sticking half an inch out from the beveled edge of the wood. This steel edge keeps the lead from buckling under influence of the flame while blowing the seam, and is much better than a wood straight-edge, as it can be applied at the proper place with no fear of its burning or annoying the operator by smoking from the heat.

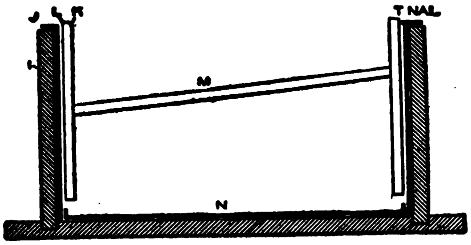


Fig. 63. Section Showing Lead Lining in Place, and Method of Bracing for Making Upright Seams.

Fig. 63 shows the lining in place, and the method of applying the brace and straight-edge to the seams that are to be blown upright in position. Letters and parts in Figs. 62 and 63 correspond, *N* in Fig. 63 being the bottom.

Unless the supply is regular and abundant, and the storage by gravity, outside tanks of ordinary capacity, if of wood, are expensive and troublesome from leakage due to shrinkage of staves above the water-line and from necessity of painting; if of iron, from change produced in the character of the water, and, freezing; cost of boxing, delivery to, and discharge from, in a frost-proof manner, etc., are common to all forms of outside overhead tanks.

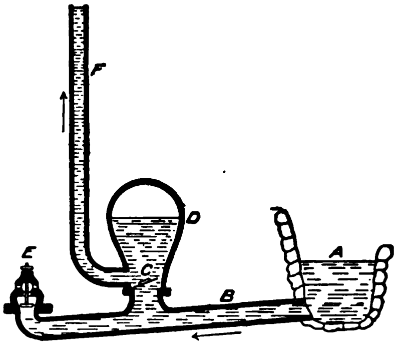


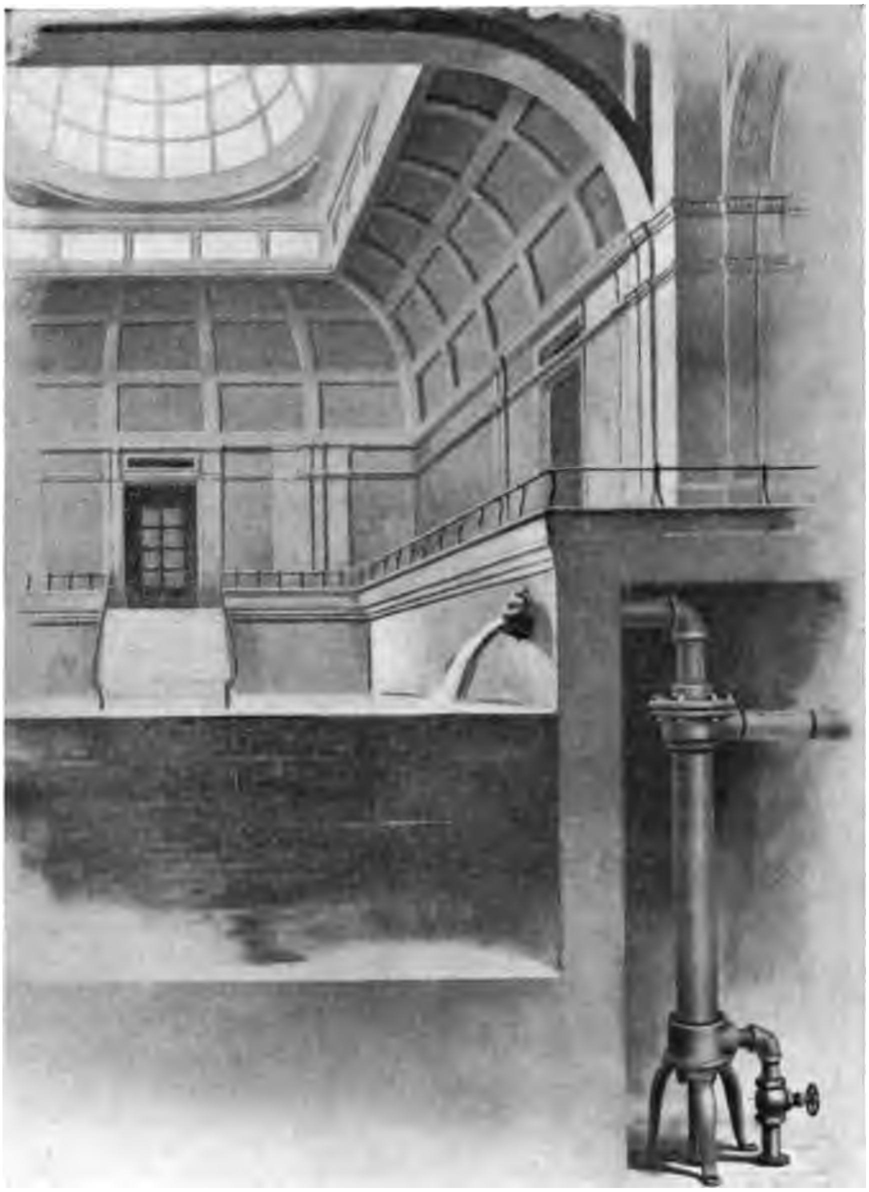
Fig. 64. Illustrating Principles of the Hydraulic Ram

A spring supply will answer if high enough to store by gravity; or a waterfall above or below the house level may be handled with a hydraulic ram if 5 to 15 per cent of the available water will suffice.

Hydraulic Ram. A ram uses the energy of a fall to elevate part of the water passing through it—one-sixth or less, according to the fall and the height to which the water is to be delivered. Four feet of fall is about as little as can be utilized to advantage; and fifty feet of liberal-size drive-pipe, even though it has to be coiled with uniform fall, is necessary to give the water momentum enough to get the best results.

Fig. 64 illustrates the elementary principles of a simple ram. *A* represents the source or spring; *B*, the drive (supply) pipe; *C*, a valve opening upward; *D*, an air-chamber; *E*, a valve tending to close downward by gravity; and *F*, the discharge pipe. In action, the water passes through the ram and out at a waste valve *E*, which is open downward until sufficient velocity is attained to lift it and close the waste exit. There being then no other means of egress, the check-valve *C*, opening upward to the discharge pipe, is forced open; and the energy of acquired momentum delivers water into the air-chamber *D* and discharge pipe *F*, until the pressure on the waste valve falls too low to hold it up (closed). The check-valve *C* then closes, and retains the water in the discharge; and the waste valve *E* falls open by gravity, leaving a comparatively unrestricted exit through which the water continues to waste with increasing force until the velocity in the drive pipe is again sufficient to repeat the impulsive delivery. Rams are made with large air-chambers, to cushion the initial strain of impulse, and should have a delivery pipe at least one size larger than the ram opening, especially if working under light fall or high delivery.

Cisterns are seldom so deep or situated so low that ordinary house force-pumps within doors cannot be used. The distance of the cylinder above the lowest level from which water may need to be pumped, is limited in all pumps alike—33 feet 9 inches atmospheric lift under *perfect* conditions, and about 25 feet under the most perfect practicable pump arrangement. Indeed, the velocity of flow into the cylinder at any point above 20 feet is so slow that in practice the cylinder should be well within a twenty-foot limit in vertical distance from the water; and the closer the better. A foot-valve strainer at the end of a cistern suction pipe will keep the pipe filled and avoid frequent exhausting of the air before water can be obtained. When a foot valve is used, means of draining the suction to below frost line, when necessary, must be provided.



SECTION OF SWIMMING POOL SHOWING WATER HEATER AT THE RIGHT OF POOL WALL

Courtesy of Federal-Huber Company, Chicago

PLUMBING

PART II

PUMPS

A common *suction pump*, shown in Fig. 65, is the type generally used in cisterns or other very short lifts. *B* is the plunger; *C*, the bottom valve; and *D*, the plunger valve. When the plunger is drawn up, a vacuum is formed in the cylinder, and water flows in through *C* to fill it. When the plunger is forced down, valve *D* opens and allows the water to flow through the plunger while *C* remains closed. Water is thus raised by the plunger at each stroke and flows from the spout in an intermittent stream. The atmospheric limit is indicated in the engraving; but, as before stated, the practical lift is taken at 20 feet or less in pumps having the plunger valve at the ground level. The plunger in this kind of pump is made to trip the bottom valve and drain the pump at will, without a waste-hole or special cock, by merely lifting the handle as high as possible.

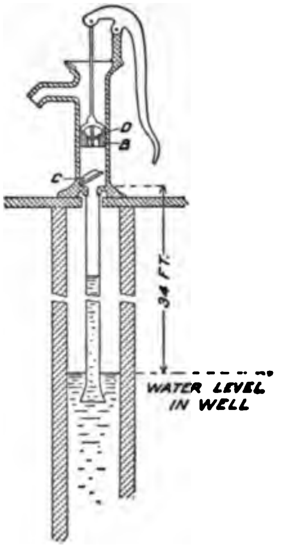


Fig. 65. Common Type of Suction Pump for Short Lifts.

When the surface of the water is a greater distance below the pump stock than ordinary suction can reach effectively, the cylinder and its working parts must be placed within the limits of lift by suction. This form is termed a *lift pump*, one type of which is shown in Fig. 66. This particular form is confined to ordinary open shallow wells or deep cisterns. It drains automatically through a waste-hole always open below frost line, located in the stock above the working barrel. There is no limit except the strength of the parts, to which a good lift pump will not bring water if the cylinder is near enough to the water and the pump in good order.

The forcing feature of a pump, making it a *lift and force pump,* is secured by working the rod of an ordinary lift pump through a stuffing box, and adding an air-chamber to take care of the surplus water pumped on the up-stroke and to expel it while the plunger is being lowered. All the water is pumped on the up-stroke of the plunger, in these pumps; and the expulsion of the surplus through the constricted spout, giving the familiar steady stream, is due to the action of the air compressed in the chamber.

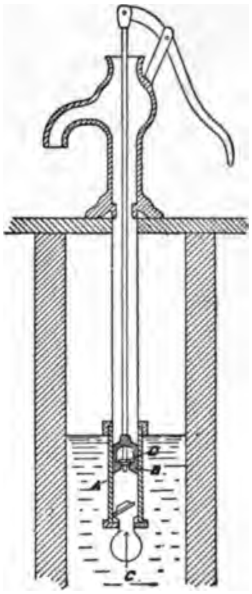


Fig. 66. Type of Lift Pump Adapted to Long Lifts.

Double-acting lift and force pumps draw water by suction on both strokes, and actually expel it by force into the discharge, the suction and force being alternate in the same cylinder on both sides of a solid plunger. The air-chamber in these cushions the delivery.

It may be stated here that hot water cannot be lifted by suction, because the boiling point of water depends upon the pressure on it. Therefore, any endeavor to create a vacuum with a pump results in vapor rising so freely as to prevent accomplishing appreciable results. Warm water can be forced by having the pump below the source, and practically allowing the water to flow into the pump by gravity.

In wells, whether driven, tubular, or open, it is advisable to have the cylinder very near the bottom. The pump standard, for hand use, should be strong, well-made, of 10-inch stroke, with rocking fulcrum, and with rod guided in perfect alignment; the handle leverage at least 6 to 1; lift pipe not less than 2 inches; rod, hollow, galvanized or wood; cylinder, at least twice the length of stroke, brass-lined, and not larger in diameter than the lift pipe—the whole being such that all valves can be withdrawn through the pipe and standard for repair or renewal without disturbing either standard body or pipe. A drain valve to empty standard and pipe below freezing point, is essential. A pump outfit of this character, to deliver water at the ground level, will require at the handle grip, 6 to 8 pounds force on

40-foot, 10 to 12 pounds on 50-foot, and 14 to 16 pounds on 60-foot wells. The lift pipe (above cylinder) should not be plain iron pipe. Polished iron cylinders ought not to be used, even though they are to be always submerged; incrustation will make it difficult to withdraw the cup-leathers—to say nothing of other objections.

The trouble with cylinders of larger diameter than the lift pipe, is the time and expense of withdrawing pipe and standard for repairs; and, of course, the power in pounds to pump with them equals the total lift *multiplied by* the sectional area of the cylinder in inches.

The importance of cylinder diameter will be better understood by comparison. A total lift of 100 feet, with cylinder 2 inches in diameter, gives 135 pounds, which, with the handle leverage at 6 to 1, will be lifted with from 22 to 25 pounds' force according to kind of rod, tightness of stuffing box, size of lift pipe, etc. With the same outfit and conditions, merely substitute a cylinder of 4 inches' diameter, and 540 pounds will then require to be lifted, which, with the same ratio of leverage, calls for over 90 pounds' force on the handle to lift the water. Then, if the lift pipe is materially smaller than the cylinder, the increase in velocity, when the cylinder water enters the lift pipe calls for an additional force that would astonish one. This should make it plain why so many pump standards are wrecked, bolts worn off, holes worn oblong, handles broken, cylinders continually needing new valves, and owners disgusted; it is all due to the lack of proper proportion of parts, and the enormous amount of needless work thus occasioned.

Total lift is the distance from the level of the source pumped from, to the point of discharge. This includes height to elevated tank, if there be one, and the distance from cylinder to water, if the cylinder is above the water; yet many mechanics are inclined to ignore the latter on the ground that the atmosphere lifts the water to the cylinder. It does, in fact; but the power of the vacuum which permits the atmosphere to lift the water, is as great as the weight of water so lifted, and the vacuum itself is produced and maintained by the energy of the person pumping.

A pump being outside for the purpose of sprinkling, filling vessels, etc., need not interfere with employing it to deliver water underground to the house and up to elevated tank. A cock-spout, a packed stuffing box, and a line of pipe below freezing from lift pipe to tank, are the essentials. Delivery to tank should be made over top of tank; and the line should have a cock and drain so that the tank pipe can be emptied when desired, and so that full force for sprinkling can be had by cutting off the tank line. When pumping to the tank, it is merely necessary to have the cock-spout closed and the shut-off of the tank line turned on.

The advantages of having the pump indoors, at the sink, are, (1) that water may be pumped for use directly; and (2) that it is not necessary to go outside in bad weather in order to fill the tank. The indoor pump will also conveniently serve ordinary purposes when other water fixtures of the house are out of repair.

Small *gasoline engines,* by means of pumping jacks or other methods of actuating, are often used to operate pumps. *Automatic electric pumps* are the most modern and satisfactory equipment for pumping soft water into house service pipes or reversing the pressure in city pipes, as shown in Fig. 67.

Windmills are a favorite means of operating outside pumps in localities where the mean wind velocity is high enough to run them economically. Light winds, and water at great depths, both contribute to increasing the size and cost of mills; while spasmodic winds require great storage capacity. If the mean wind velocity is under 7 miles per hour, mills are suited to very light pumping only. Windmills require self-priming pumps—that is, pumps that are always ready to pump water without adding priming or working rapidly to get water to the cylinder. They are also provided with governors to avoid pumping after the tank is full, and with means which high winds will automatically operate, for folding the mill out of the wind. Light winds and severe duty are counterbalanced to some extent by gearing the wheel for higher speed than is communicated to the actuating rod.

Hot-air engines can be used indoors if the supply is within the vertical distance limit and not too far from the house. If the well or source is far away, it is best to build a frost-proof house for the engine, close to the source or over the well, so that direct connection to pump-rod can be made. Hot-air engines, like gasoline engines, depend on the momentum of the speed wheel doing the work through part of the interval. In the double-cylinder type, heat from wood, coal, gas, or oil expands the air under the piston of the power side, and drives it up. At the same time, the other piston draws the air over through a heat accumulator of iron plates, where it comes in contact with a water-jacket that is filled by passing the pump discharge through it, the air thus losing some of its heat by imparting it to the water in the jacket. The same air is then forced back through the accumulator, where it reabsorbs some of the heat previously parted with, and is compressed in its partially cooled state in the bottom of the cylinder on the combustion side, where, by again absorbing heat from the fuel, the process is caused to be repeated.

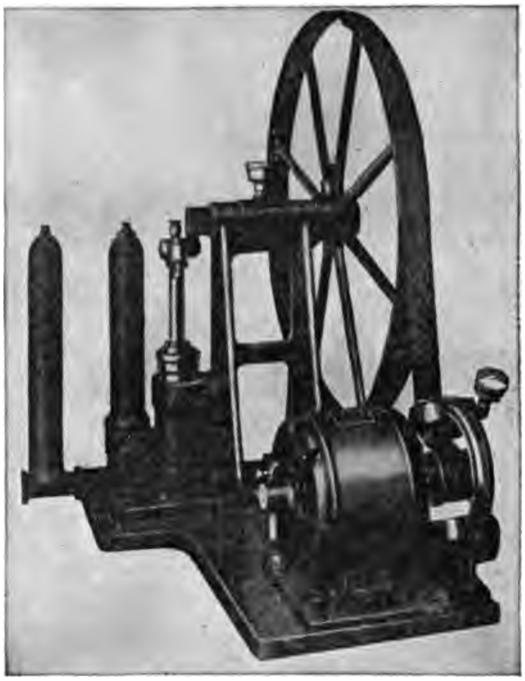


Fig. 67. Automatic Electric Water Pump with ¼-Horsepower Motor for Pumping Water into House Service Pipes or Increasing City Water Pressure.

Courtesy of Crane Company, Chicago.

Hydraulic water-lifts have of late years been used to elevate water by water-pressure. With them various arrangements of piping to suit a wide scope of conditions are possible. If city water pressure does not reach the upper floors, the pressure on the lower floor may be employed to lift the supply for the upper floors, either for direct use from the pipe as usual, by aid of a closed accumulator, or by first delivering the water elevated into an open tank and then piping as in the ordinary tank installation. The power-water of a lift (that used to elevate with) is not wasted as in the case of a ram. The service for the low-level fixtures is simply carried through the power cylinder of the lift, and elevation takes place only during the use of faucets connected to the street pressure. The amount of water elevated is therefore governed by consumption on the lower floors; and the ratio of amount elevated to that used directly from the initial pressure, is as the capacity of the power cylinder to that of the one operated by it. An approximate estimation

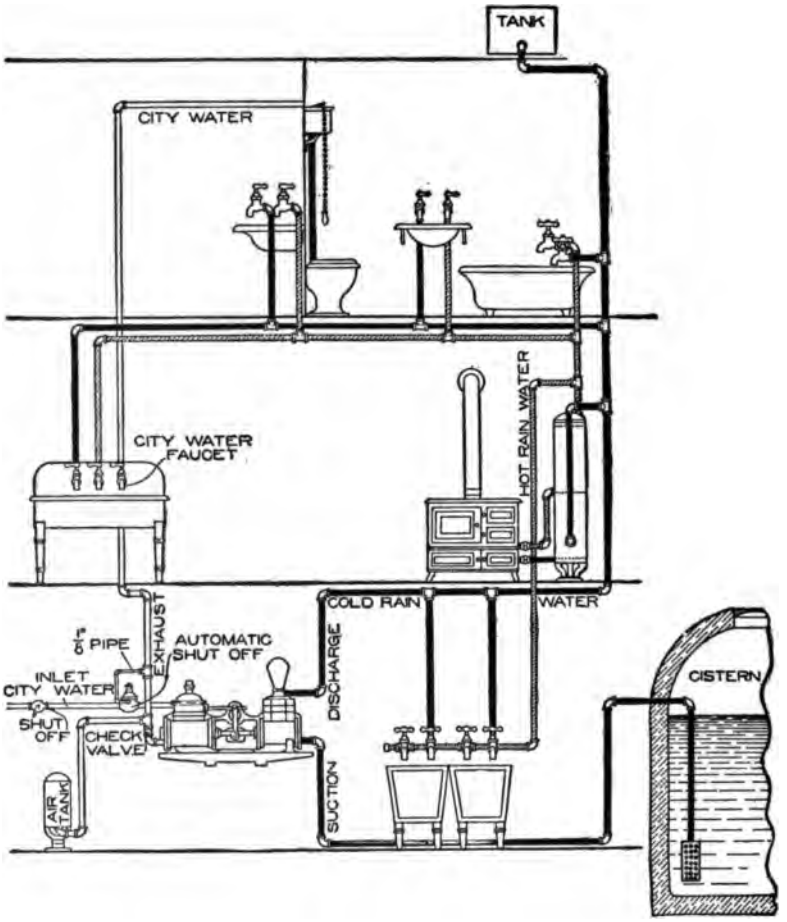


Fig. 68. Method of Using City Pressure to Pump Soft Water for House Supply.

of the relative amounts of elevated and initial supply needed, must, on this account, be made before a proper lift can be selected.

Cistern water can also be lifted by this method to either an open or closed tank, using or wasting the power-water according to circumstances. In Fig. 68 is shown a plan by which hard city water pumps rain water for baths, trays, etc., by means of a water lift.

Domestic supply by what is termed the *Pneumatic System*, is a feature of modern plumbing in many isolated buildings. The manner of pumping, though it may be accomplished by any of the means mentioned, is usually by hand pump. Instead of the open elevated tank supplying the fixtures by gravity, a closed tank capable of withstanding the required pressure is placed either in the cellar or in the ground. The pump is connected with the tank at the bottom, with a check-valve between the pump and tank. The house service is also taken from the bottom of the tank. Pumping the water in, crowds the air in the tank into the upper portion, so that, by the time the tank is three-quarters filled with water, there is in the neighborhood of four atmospheres' (or 45 pounds') pressure on the gauge. At one-fourth full, the gauge pressure would be 7½ pounds; one-half full, 15 pounds; seven-eighths full, 105 pounds. When the tank is placed horizontal, the simple definite relation of altitude of contents in the tank to contents is in evidence only at half-full. Above the center the percentage of contents exceeds that of the altitude, while below, it is less. With vertical tanks however, as shown (level), the altitude is always in proportion to the contents. Part of the storage tank being occupied by air, and much of the water in it not available under the pressure thus established, higher pressures are often employed, either by pumping air into the tank with a separate pump, or by

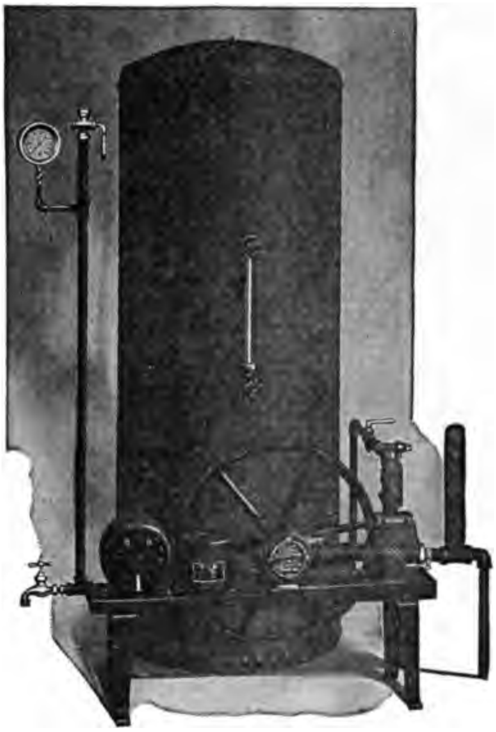


Fig. 69. Hydro-Pneumatic Water System with Electric Pump.
Courtesy of Crane Company, Chicago.

use of a pump delivering both water and air. The former is the more satisfactory.

A type of pneumatic service apparatus is shown in Fig. 69. The good features of these systems are that cheap and permanent support for the tank is secured; the water is kept cool in summer and free of frost in winter; and, if sufficient capacity is provided, fire-pressure for a time can be obtained. The disadvantages are that plain iron cylinders injure the water; galvanized cylinders are costly; large cylinders are hard to make and keep air-tight through the strain of transportation and installation; calking seams is expensive; a battery of small cylinders offer numerous seams and connective joints as chances for leakage, and only a fraction of the water is available under ordinary pressure; high pressure is severe on the pump and parts; and hand pumping is very laborious. Pressure higher than necessary for the purpose, is useless expense in any system.

WASHER AND HYDRANT

Assuming that a house is to be piped from city pressure, the fixtures of the yard are nearly always a street washer and yard hydrant. The principle of these is the same; but the washer is primarily intended for the attachment of hose for sprinkling purposes, while the hydrant body extends above ground so that vessels may be placed under the nozzle to have water drawn into them. The hydrant may be used to draw either with or without a hose thread on the nozzle, while no use of the street washer is possible without the thread; hence there may be a material difference in the water rates, according to the possible uses the water can be put to.

The valve of these fixtures is placed at the bottom, 2 to 5 feet below the surface, according to climate. The working parts can be withdrawn for repairs without disturbing the body. Waste-holes are open when the pressure valve is closed, so that the stem and body will empty to below the freezing point. The pressure waste-hole is not entirely closed until the hydrant or washer is approximately wide open. For this reason, turning the water only partly on when drawing or sprinkling, while it does no apparent harm, is likely to lead to trouble. If the ground is clay, it does not soak up the waste. If there is a cellar near, it will sooner or later find its way into it.

Even if care is taken in this regard and the hydrant valve fully opened when in use, there is a liability to serious dampness from the wastage into the ground of the water stored in the standpipe above the valve, which is always after a short period discharged below the ground-level through the waste-hole.

The least trouble one may expect from careless use is that the ground around the fixture will be saturated, and the body stand full of water instead of draining away; and when cold weather sets in, damage by freezing will result. The action of frozen ground in pulling up on the body of these fixtures is severe. To avoid trouble from waste water and frost, certain precautions are taken in good work. The end of an iron pipe is too rigid for direct connection. To overcome this, fittings and nipples are added so as to make the connection indirect and secure the required spring in the joints and pipe, as well as freedom from torsion. A short piece of lead pipe answers the same purpose. A cavity formed about the base of the fixture and connections, permits freedom of action and greater immunity from frost breakage.

Usually, the only positive way to insure the waste water draining away harmlessly, is to bore a dry-well under the fixture and fill it with broken rock or fragments of hard brick. This filling should extend a little above the bottom of the fixture, and should have a stout cloth folded about the body and tucked down around the brick at the edges so that the earth cannot wash in and choke the crevices of the filling.

SERVICE PIPES

The supply to the house should have a stop and waste immediately outside the wall—or, preferably, just within the wall if the cellar is frost-proof. For outside use, the iron case box is best. Combination stop and waste cocks or valves of similar principle are generally used for this and all other shut-off purposes in plumbing work, where the waste feature is permissible at all. Two separate valves or cocks serve the purpose perfectly, of course; but the waste is likely to be forgotten, thus leaving the pipe filled and subject to frost. Merely closing the stop and opening the waste on a closed line will not, however, drain the pipe. It is necessary, also, to open the faucets in the house, in order that air may enter at the upper end of each line and counterbalance the atmospheric pressure at the waste so that the water will run out by gravity. If the pipe is sagged at any point, the water retained will have to be blown out with the lungs. If the pipe is trapped by reason of its course, the trap is, or should be, provided with a drain cock, and this must also be opened to insure thorough draining. Air-chambers usually drain without attention as they are only partially filled by compression of the air trapped in them, and when the pressure is off, the air expands again and drives the water out.

While speaking of draining pipes, it may be well to mention the draining and protection of waste traps from frost as well. Closet tanks can be drained by simply pulling the chain when the water is off. The bowl may be emptied with a sponge or rag; but, as communication would thus be opened between the house and soil pipe, this plan is not advised for any kind of trap. Common salt added to the water in the trap will prevent freezing until the contents chill below zero, Fahrenheit. Caustic soda lowers the freezing point, and may be used in earthenware with impunity; but while it has shown no noticeable effect on metals, it should be used with caution, if at all, in both metal and porcelain-enameled iron fixtures. Glycerine and wood alcohol added in equal parts to make a 30 per cent solution in the trap or fixture, will prevent freezing above zero. If the house is being drained for a considerable period of disuse, the best anti-freezing and seal-protecting filling for ordinary traps is, perhaps, glycerine alone. It has the advantage of doing no injury whatever to any material used in such goods, and it will not evaporate.

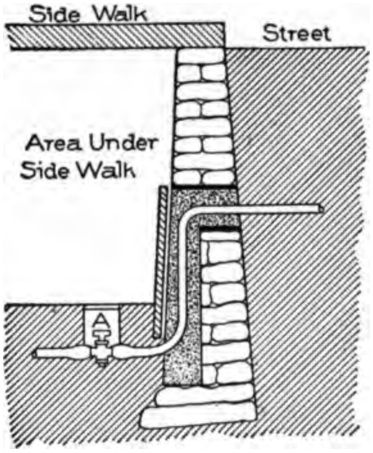


Fig. 70. One Method of Protecting Service Pipes from Frost. Pipe Carried through Wide Channel in Wall and Packed in Mineral Wool.

While it is sometimes necessary to place pipe in exposed positions, plumbing is not satisfactory if so exposed as to freeze during regular occupancy of the house; and every precaution should be taken to locate the fixtures and design the pipe system so that freezing will be unlikely. When exposure cannot be avoided, placing the hot service below the cold on horizontal runs; providing circulation in the hot service so placed; provision for circulation in, or otherwise warming, the cold service; and employment of liberal air-chambers, may singly or otherwise reduce the trouble from freezing to a minimum. Fig. 70 illustrates the precaution taken in one instance to protect the service in a cold-climate job. Water for the whole job always depends upon the service being in working order, and in this case the character of the ground prohibited drilling down to carry it under the area wall. The wall is shown liberally channeled, thus making three walls and the ends of the box of stone. The pipe is packed in mineral wool. The main stop and waste cock is shown at *A*.

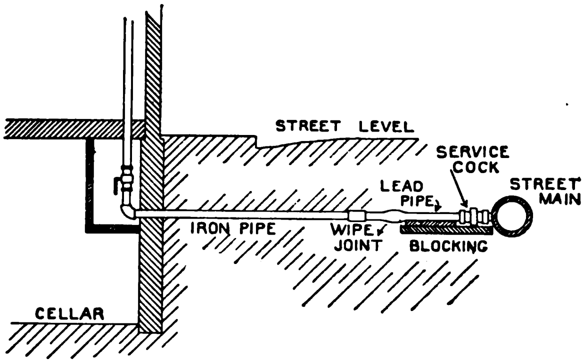


Fig. 71. Iron Service Pipe Connected to Street Main by Lead Pipe to Secure Flexibility and Avoid Effects of Settling.

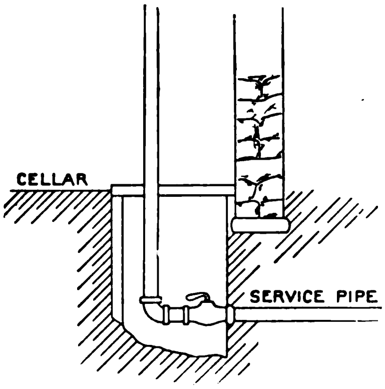


Fig. 72. Service Pipe Carried beneath Foundation Wall.

Fig. 71 shows a method of securing flexibility necessary to compensate for settling when connecting an iron service pipe with the street main, a section of lead supply being wiped in next the main. The service box and stop-cock at the curb are not shown in the engraving. The earth under the pipe should be rammed down solid after the connections are made, so that pressure from above will not break the connection or strain the cock. The connections between the lead and iron pipes should be made by means of brass ferrules and wiped joints. A stop and waste cock should be placed in the service pipe just inside the cellar wall, and in a position where it will be accessible in case of accident. A drip pipe should be connected with the cock tube, for draining away the waste water, which would otherwise saturate the frost-proofing and chill the pipe by conduction.

Simple boxes with multiple walls with air-space between, may be employed in protecting pipes against frost; or a single box with mineral wool, hair, felt, shavings, or granulated cork may suffice. When the service is brought under the foundation before entering the cellar, as shown in Fig. 72, frost-proofing is seldom necessary.

DIRECT SUPPLY

The salient features of the supply system for city pressure, not already mentioned, are; separate shut-off cocks for the supplies of each fixture; separate lines to each isolated fixture or to each group of fixtures; ¾-inch supply to all sinks, trays, and baths; ½-inch supply to water-closet tanks; and ½ or ⅜-inch branches for lavatories; no traps in supply lines; return circulation from lavatory hot supply so that hot water can be drawn instantly at the lavatory faucet; storage cylinder for hot water amply large to furnish a hot bath without robbing the hot service for other purposes; faucet on sediment pipe, so that water can be drawn at that point when desired; and proper stove connection. All shut-offs in direct-pressure work, except where located immediately at the fixture, should be ***stop and waste***, with the waste on the house or fixture side.

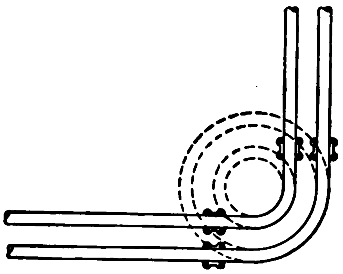


Fig. 73. Method of Laying Out Concentric Bends in Parallel Pipes.

On single runs of lead pipe, make all bends on the same size of pipe, of the same radius. Make no bend on any size pipe, except tubing, of less than 3-inch radius to the center of the pipe. Give ⅝ and ¾-inch pipe bends 3-inch radius; and ⅞ and 1-inch pipe bends, 4-inch radius. Where two pipes of different size run together and bend in opposite directions, give the bend of the smallest pipe the radius prescribed for the bend in the larger one, if practicable.

TABLE III

Data Relating to Offsets in Iron Pipe Work

Bend	Equal to	Multiply by
1/6	60 °	1.15
1/8	45 °	1.414
1/12	30 °	2.00
1/16	22½°	2.61
1/32	11¼°	5.12
1/64	5⅝°	10.22

Where more than one pipe bend in the same direction, make the bends of the pipes form arcs of concentric circles as shown in Figs. 73 and 74. To set off the offsets in Fig. 74, draw line *A*, at the end of the first bends; and with the proper radii, describe the arcs that outline them. Set off one-eighth of the circumference of the circle corresponding to the larger arc, and draw line *C*, cutting the center of the circle. Then produce dotted line *D*, and set off a square the diagonal of which will give the straight pieces of the offset desired; and produce *E* parallel to *C*. Next describe the arcs outlining the second bends, finding the center on *E* from radius equal to the corresponding radius at *A*, which will be the intersection for *E* and *B*. This brings the offset parts the same distance apart as the runs are. To accomplish this result with iron pipe, the centers of 45-degree fittings would have to be placed at the intersections of tangents of the arcs extended, thus throwing the fittings in a line deviating 22½ degrees from one perpendicular to the run. This plan is the strictly correct way for iron pipe, as well as lead pipe work; but on account of the

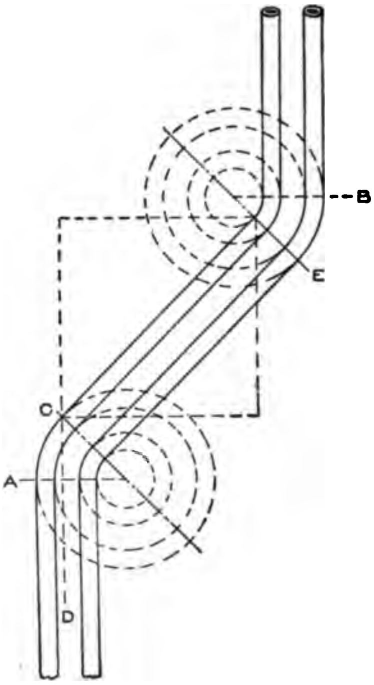


Fig. 74. Method of Laying Out Offset in Parallel Pipes to Preserve Equal Distance between Them

difficulty of laying out the work, it is more usual to line up offset fittings perpendicular to the runs, and let the offset pieces fall, as they will, nearer to each other, center to center, than are the lines of the runs.

Offset pieces from center to center of fittings exceed in length the distance offset in the ratio indicated by the constants given in Table III. To find the length of an offset piece, center to center of fittings, simply multiply the distance the line is to be offset, by the constant given for the particular fittings to be used.

Water Supply to Fixtures. In a small installation, the running of a separate supply to each fixture is desirable. There is, however, a limit to the number of fixtures and isolated location of them, beyond which the furnishing of separate supplies to each faucet is folly, as, in addition to the confusion of pipes, and the expense, it leaves more material open to possible failure, and does not reduce the chances of lack of service in porportion. The sole object of separate supplies (and of cocks, too) is to avoid losing the service of other fixtures during times when one of them, or its supply or waste, must be repaired.

In a residence job, two main supplies to each bathroom, with separate stops for each fixture, are sufficient; and a return circulating pipe from the lavatory will serve every purpose, as the water is kept hot in the main line to the bath branches.

The pump and kitchen-sink work of a country job of this type is shown in Fig. 75. The pump air-chamber discharge leads up to and over tank. An opening near the pump provides for elevating water by other means if desired. The pump faucet is piped up and over so as to discharge into sink. The tell-tale pipe from tank leads down behind sink-back and out through a nozzle, as shown. The sink supplies are fitted with stop-cocks. The pressure being light, there are no air-chambers to the sink faucets. The supply to pump is from a large cistern.

Fig. 76 shows the supplies of the same job, on the kitchen ceiling. The system provides positive circulation to keep hot water near the bathroom fixtures. The hot supply is on the left side for each fixture. There is only one pipe crossed, and it does not interfere with draining the job. There are no traps in the supplies, nor drain cocks, to be forgotten. There is a relief line from the reservoir to the tank, so that it is not possible to close every means of escape for vapor or steam

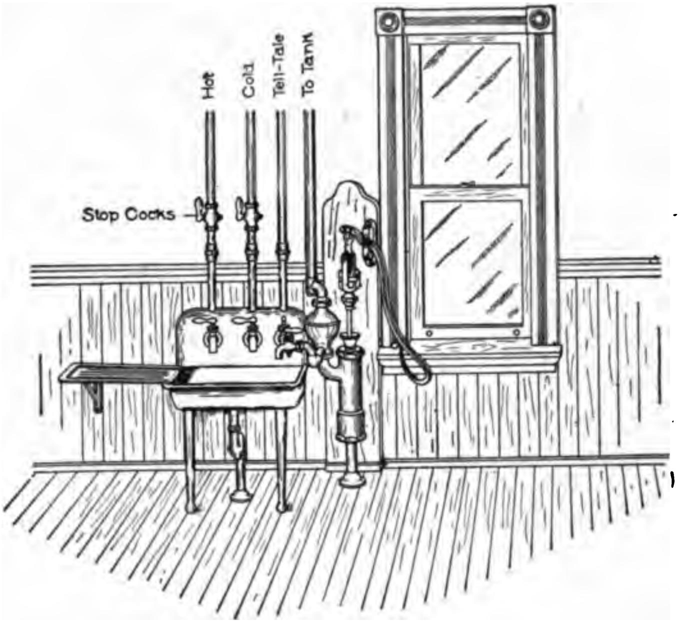


Fig. 75. Pump and Kitchen-Sink of a Country Installation.

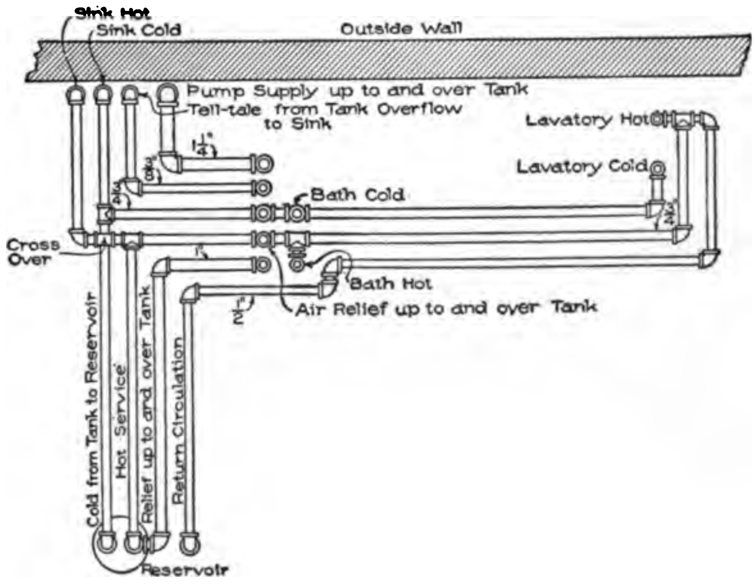

Sink Hot
Sink Cold
Outside Wall
Pump Supply up to and over Tank
Tell-tale from Tank Overflow to Sink
Lavatory Hot
Lavatory Cold
1¼"
¾"
¾"
Bath Cold
¾"
Cross Over
1"
Bath Hot
1½"
Air Relief up to and over Tank
Cold from Tank to Reservoir
Hot Service
Relief up to and over Tank
Return Circulation
Reservoir

Fig. 76. Plan Showing Layout, on Kitchen Ceiling, of Supply Pipes in Installation Shown in Fig. 75.

arrangement of one may be deduced from the *modus operandi* of the other. The vertical type, for example, of iron or mild steel, galvanized inside and out, single- or double-riveted, heavy, and calked according to pressure designed for, is generally divided into two classes—*Standard* and *Extra Heavy*. Seamless copper cylinders, reinforced inside for heavy work, are made.

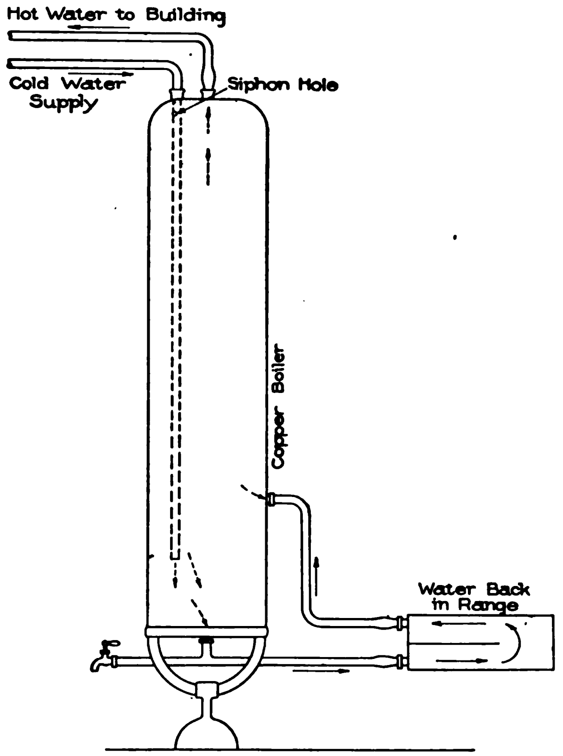


Fig. 78. Vertical Type of Hot-Water Storage Cylinder Adapted for Range Heating.

The light copper shells for light pressure, not reinforced, are collapsible under partial vacuum, and frequently do collapse when the supply is being drained, on account of the delivery failing to admit air to take the place of the water. Copper shells are also much more likely to rupture under strain than iron or steel shells. Take, for instance, a house with copper storage cylinder, with hot fire and in extremely hot water, as on wash-day; then, if the pressure is suddenly reduced by opening a faucet or otherwise, and the temperature is far above the boiling point of the water under the remaining pressure, the tendency is for the whole volume of water to turn instantly to steam. This has happened with disastrous effect in more than one instance, the copper shell being ripped and spread out almost in a plane.

Rumbling noise is frequently heard in any type of reservoir. Water being heated throughout, or perhaps only at some points in the stove, to above the boiling point corresponding to the pressure, steam bubbles form in the hottest places and crowd the water-back into the main or into the air-chambers to make room for themselves. It is the concussion caused by the collapse of these bubbles forming and condensing in rapid succession, that creates the rumbling noise. This condition sometimes results from a brisk fire when the reservoir water is not overheated, and is due to air-traps in the connection, or constriction by incrustation or otherwise. Rumbling under this condition is a cause for prompt investigation.

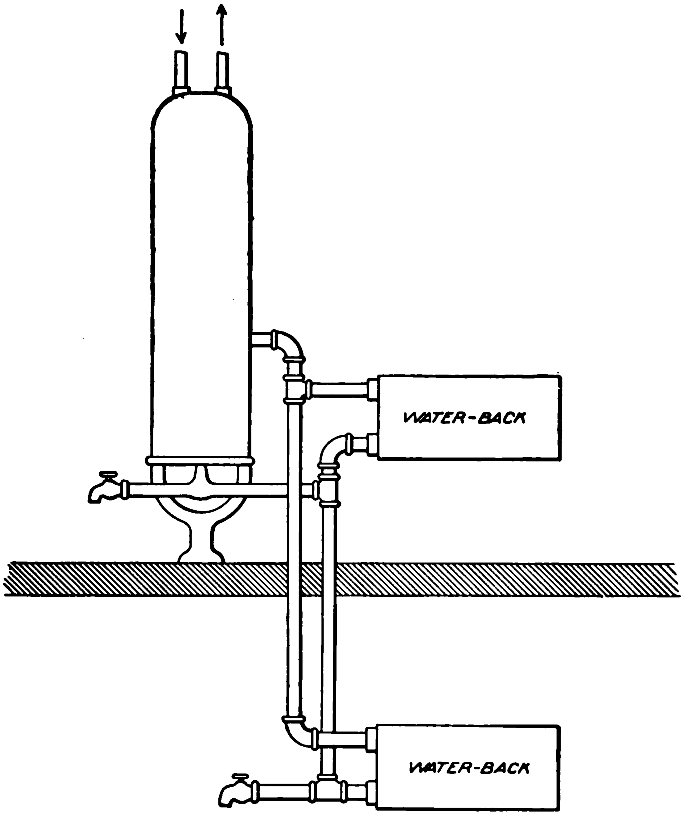


Fig. 79. Method of Connecting Reservoir to Two Water-Backs on Different Floors.

The means of heating may be a cast back or front, or a hand-made pipe coil in the firebox. Air-traps favoring the formation of steam are occasioned by wrong inclination of the connection, by reduction of its diameter in the horizontal part, or by the upper hole of a cast back being tapped below the top of the water cavity. The bottom of a reservoir is below the firebox level when placed on the regular stand. When it is desirable to connect a reservoir with two water-backs, one in the kitchen range for regular service and another in a laundry stove in the cellar, the plan of connecting them seen in Fig. 79 is proper. In this case, either stove may be used separately, or both together, as occasion demands. The sediment cock of the upper reservoir may be handy to draw from at times; but the lower one will be found to collect most of the sediment, and should be opened frequently to cleanse the water-back and connections.

In laundries, public bathrooms, etc., where a large amount of hot water is used, it is necessary to have a larger storage tank and a heater with more heating surface than can be obtained in the ordinary range water-back. Fig. 80 shows an arrangement for this purpose, using the horizontal type of storage tank. The tank may be of galvanized wrought iron or steel, any size desired, and is usually suspended from the ceiling by means of heavy iron stirrups, pipe standards being placed from stirrups to floor for the larger sizes, while brick piers are best and usual for extra large tanks of 500 gallons or more. The heaters used are similar to those employed for hot-water house warming. The simplest method of making the connections is indicated in the illustration. If the supply is from a street service, or there are faucets on the storage tank below the hot storage reservoir level, allowing the tank to become empty through those faucets or failure of the street supply, there should be a check-valve in the cold-water connection.

The *capacity of the heater and tank* employed will depend upon the amount of water used. In some cases a large storage reservoir and a comparatively small heater are preferable, and in others the reverse is more desirable.

The required grate surface of the heater may be computed as follows:—First determine or assume the number of gallons to be heated per hour, and the required rise in temperature. Reduce gallons to pounds by multiplying by 8.3, and multiply the result by the required rise in temperature to obtain the number of thermal units. Assuming a combustion of five pounds of coal per square foot of grate, and an efficiency of 8,000 thermal units per pound of coal, we have the formula:

$$\text{Grate surface in sq. ft.} = \frac{\text{Gal. per hour} \times 8.3 \times \text{Rise in temp.}}{5 \times 8{,}000}.$$

Example. How many square feet of grate surface will be required to raise the temperature of 200 gallons of water per hour from 40 degrees to 180 degrees? Substituting values in the above formula, we have:

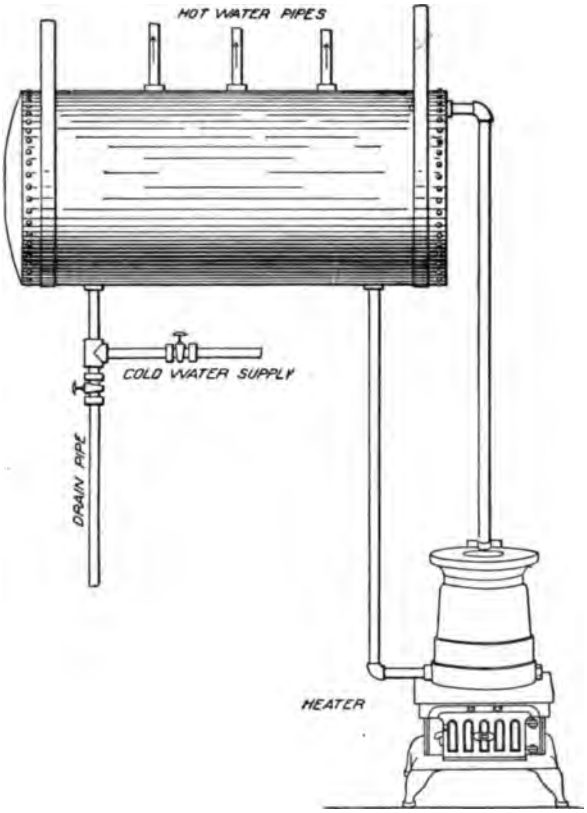


Fig. 80. Horizontal Type of Hot-Water Storage Cylinder Connected to Heater.

$$\frac{200 \times 8.3 \times (180 - 40)}{5 \times 8{,}000} = 5.8 \text{ square feet.}$$

In computing the amount of water required for bathtubs, it is customary to allow from 20 to 30 gallons per tub, and to consider that the tub may be used three or four times per hour as a maximum during the morning. This will vary a good deal, depending upon the character of the building. The above figures are based on apartment hotel practice.

Storage cylinders or reservoirs for hot water are often called *boilers*, but will henceforth be referred to as *reservoirs*. A stove or range connection is essentially described as follows: The sediment pipe should terminate in a faucet at the lowest point in the bottom connection, which connection should rise continuously from the lowest point to the bottom hole in the heater. No direct connection should ever be made between the water supply pipes and the drain. Even if such a connection is above the trap of a fixture, there is some danger that foul liquids or gases may penetrate for some distance into the supply pipes and thus afford a possibility of contamination of the water supply. The upper connection should rise continuously from the upper hole of the heater to the hole in the side of the reservoir; or, if preferred, in order to get hot water instantly after the fire begins, the upper connection may rise and connect into the main hot service over the reservoir. The circulation will be the same; but in general, connecting at the hole in the side gives best results, though in this case the first portion of water heated mingles with the balance in the upper end of the reservoir, and the following portions in succession, so that no *hot* water can be obtained until all the water above the side hole is warmed. The bottom hole serves for emptying, cleansing, and circulation to the stove.

The return circulation is always connected to the bottom pipe of the stove connection, as shown in Fig. 81, in which the hot service and circulating pipe are represented by dotted lines. The side hole is simply to receive the water from the stove. There are, or should be, two holes in the top, one in the center of the head, and the other about half the radius in the direction of the side hole. The concentric hole is for cold-water entry. The cold supply might be admitted at the bottom, but the result would be to empty the reservoir when the house supply is turned off. The cold supply is not emptied abruptly into the top of the reservoir. A delivery pipe is extended to very near the bottom, say within two or three inches, so that the water will mingle directly with the coldest portion near the bottom, where it begins its journey to the stove to be heated. The usual way is by simple open-end pipe, but the end of the pipe should be plugged and holes drilled in the pipe and plug so as to form a spray delivery. This does not aid the delivery or heating at all, but the spray will scour the bottom and sides adjacent when the reservoir is emptied and flushed to rinse out scale and sediment. Immediately under the upper head, the delivery pipe must have a $\frac{1}{8}$-inch hole drilled in, so that air will enter and break the siphon, and thus avoid inadvertently emptying the reservoir when intending only to cut off the supply and drain the pipe. See Fig. 78.

The *siphon hole,* as it is termed, should be turned in the direction opposite the eccentric hole, which is for the hot-water exit, so that the stream of cold water which issues there when water is coming into the reservoir will not cut across and interfere with the hot service which is always leaving the reservoir at the same time. If the delivery were placed nearest the side hole, hot water from the stove would have to pass around it in order to reach the exit. Delivering the cold through a pipe passing down through the volume of hot water is no material retardation of the heating process. The heat thus absorbed by the cold delivery is simply that much aid to the ultimate purpose. This cannot be said of the siphon-hole jet when directed across the hot exit or in its direction.

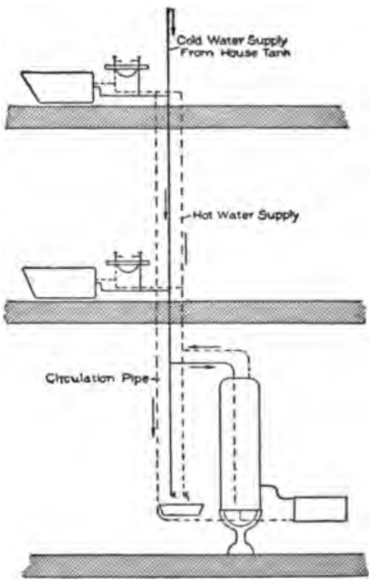


Fig. 81. Pipe Connections to Heater and Fixtures. Hot Service and Circulating Pipe Shown by Dotted Lines. Return Circulation Connected to Bottom Pipe in Water-Back.

The object in putting the siphon-hole near the upper head is to avoid siphoning more water than necessary, as the waste tubes of stop and waste cocks are generally left open—not connected to drains, and often not even discharging where the waste can be left to take care of itself. Moreover, it is a waste of the stored hot water to siphon out several inches from the hottest point.

Care should be taken not to have the hot connection extend into the upper head below the inner surface, as this would form an air-space which could not be filled with water, and thus annoying noise and the formation of steam would be favored, if no other consequence presented itself.

It is essential to keep the water-back or coil filled. Sometimes the supply may be off for a day or so. No water can then be drawn at the regular faucets; and extreme care should be taken not to draw too much from the sediment faucet, as this is the time when temptation to use it is hard to overcome. The reservoir full will keep the level above the side hole for weeks, if none is deliberately drawn out. The height of the water can be told by tapping on the shell, and in no case should it be allowed to fall below the side opening; neither will it do to empty the reservoir and use the fire with the back empty. Either keep water in the reservoir in cases of emergency, or remove the water heater altogether and substitute a tile back until regular water supply can be had. A reservoir can be replenished with a pail and funnel, by hand, by loosening one of the top connections.

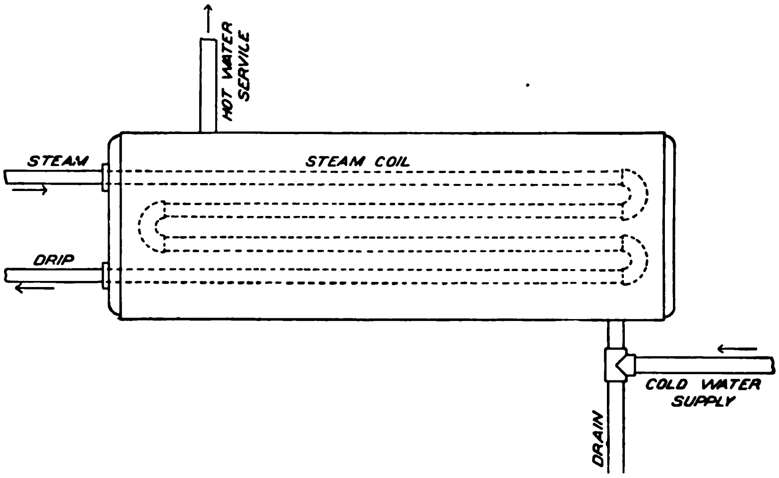


Fig. 82. Horizontal Hot-Water Storage Reservoir with Steam Coil of Brass Pipe for Heating. Used Where Steam Pressure is Constantly Maintained.

In apartment or other houses where steam pressure is constantly maintained, the whole plumbing system is usually supplied with hot water through the medium of a reservoir provided with steam coil of iron, brass, or copper pipe, as shown in Figs. 82 and 83. The *trombone* *coil*, illustrated in Fig. 82, can be used only on horizontal tanks; it would not drain in any other position. The condensed steam is wasted into the sewer, delivered to a hot well, or returned by steam trap.

The efficiency of a steam coil when surrounded by water is much greater than when placed in the air. An iron pipe will give off about 200 thermal units per square foot of surface per hour for each degree difference in temperature between the steam and the surrounding water. This is assuming that the water is circulating through the heater so that it moves over the coil at a moderate velocity. The condensing power of galvanized pipe is very nearly the same as that of plain iron, its coating being an alloy and not pure zinc as is generally supposed. The ratio of absorption decreases as the temperature of the water approaches that of the steam surface. In assuming the temperature of the water, take the average between that at the inlet and that at the outlet.

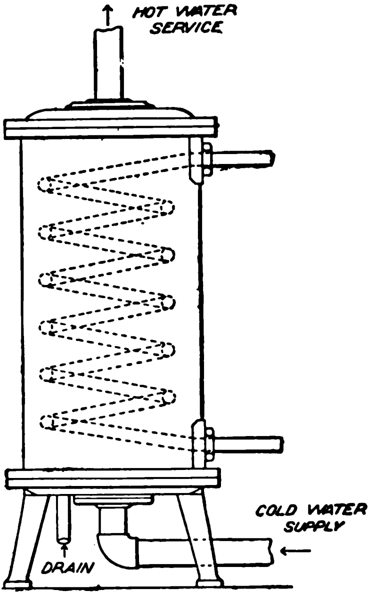


Fig. 83. Vertical Storage Reservoir with Steam Coil of Iron, Brass, or Copper Pipe for Heating, Used Where Steam Pressure is Constantly Maintained.

Example. Find the heating-surface required in an iron coil to heat 100 gallons of water per hour from 38 degrees to 190 degrees, with steam at 5 pounds' pressure?

Water to be heated = 100 × 8.3 = 830 pounds.

Rise in temperature = 190 − 38 = 152 degrees.

Average temperature of water in contact with the coils

$$= \frac{190 + 38}{2} = 114 \text{ degrees.}$$

Temperature of steam at 5 pounds' pressure = 228° approximately (actually 227.964°).

The required B. T. U. per hour = 830 × 152 = 126,160.

Difference between the average temperature of the water and the temperature of the steam = 228 − 114 = 114 degrees.

B. T. U. given up to the water per square foot of surface per hour = 114 × 200 = 22,800. Therefore,

Number of feet of heating surface required = 126,160 ÷ 22,800 = 5.5 square feet of surface or 12.6 lineal feet of 1¼-inch, or 16 lineal feet of 1-inch pipe.

per square foot, per hour per degree for 100° difference, to 228 B.T.U. for 125° difference. The relative condensing power of submerged iron, brass, and copper pipe is about as 2, 4, and 5, respectively. Within the range of water temperatures usual in practice and with steam at ordinary pressure, we may safely place the condensing power of iron, brass, and copper pipe in even tenths, .2, .4, and .5 pounds per hour, per square foot, per degree difference between the steam and mean temperature of the water. With these values, the latent heat of steam, say 960, should be used in converting heat units, found as in preceding examples, into "pounds" of steam. Having this latter, the process of finding the coil surface would be: multiply the temperature difference by the constant .2, .4, or .5, according to the kind of pipe coil to be used, and divide the "pounds" of steam by the product so obtained. The result will be coil surface in square feet, which may be converted into lineal feet by multiplying by 2.9 for 1-inch pipe; by 2.3 for 1¼-inch pipe; by 2. for 1½-inch pipe, and by 1.6 for 2-inch pipe. As in some of the previous examples three feet of 1-inch pipe are generally taken as one square foot. Sometimes a storage tank

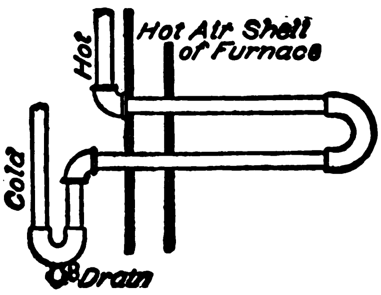


Fig. 86. Cross-Connection of Storage Tank to Firepot of Furnace

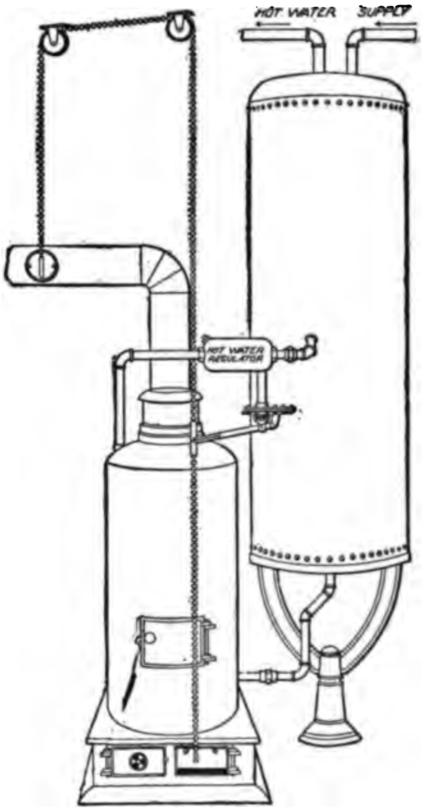


Fig. 86. Temperature Regulator Attached to Coal Heater.

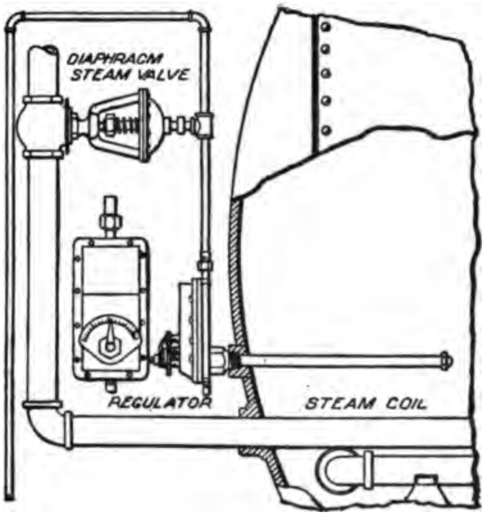


Fig. 87. Temperature Regulator Connected to Steam Coil.

is connected with a steam-heating system for winter use, and cross-connected with a coal-burning heater for summer use when steam is not available. Such an arrangement is shown in Fig. 84. A cross-connection for the same purpose is often made to the fire-pot of the house-warming heater, as indicated in Fig. 85. A drain at the lowest point is essential, but so deep a dip as shown is not necessary.

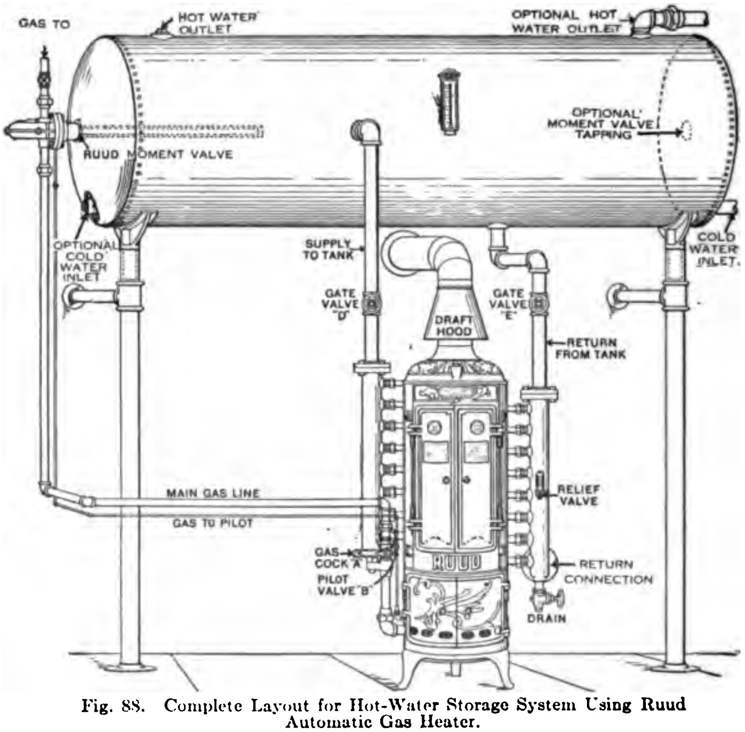


Fig. 88. Complete Layout for Hot-Water Storage System Using Ruud Automatic Gas Heater.

Temperature Regulation. Hot-water storage tanks having special heaters or steam coils, should be provided with some means for regulating the temperature of the water. Fig. 86 shows a simple form attached to a coal-burning heater. An outer shell is connected with the circulation pipe as shown in Fig. 86. An inner chamber connects with a space below a flexible rubber diaphragm in a separate case adapted to operate the draft lever.

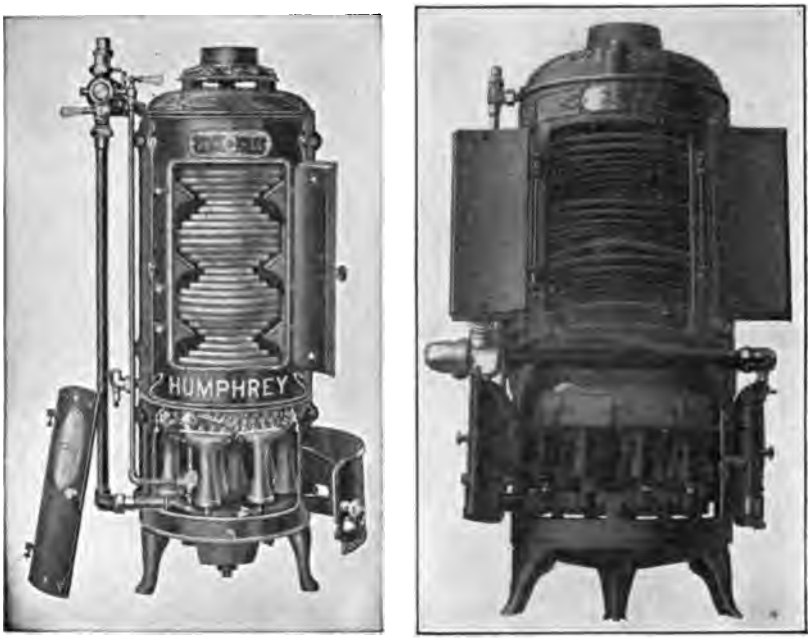


Fig. 89. Typical Automatic Gas Heaters for Instantaneous Hot-Water Service
Left—Humphrey Heater; Right—Ruud Heater.

A form of regulator for use with a steam coil is shown in Fig. 87. This consists of a rod made up of two metals having different coefficients of expansion, and so arranged that the difference in expansion will produce sufficient movement to open a small valve when the water reaches a given temperature. This allows water pressure from the street main with which it is connected, to flow into a chamber above a rubber diaphragm, thus closing the steam supply to the coil. When the water cools, the rod contracts, and the pressure is released above the diaphragm, the valve opening to admit steam again.

Return circulation is provided in these installations in the way already described, being even more essential than in small jobs with shorter runs and fewer fixtures; yet one would think that the great number of fixtures served would insure at least one or another being in constant use, and thus keep warm water in the main lines without special provision for the purpose.

In cottages with no bath and with small culinary requirements, a 30-gallon reservoir is sufficient. Not less than 40 gallons should be employed for a bathroom job. The capacity of the average stove heater is even too great for 40 gallons' storage unless there is liberal use of hot water; but where gas is used and the water heating independent of the cooking heat, as it generally is, the temperature can be regulated to suit. A storage capacity of 52 gallons or more is usual for large residences.

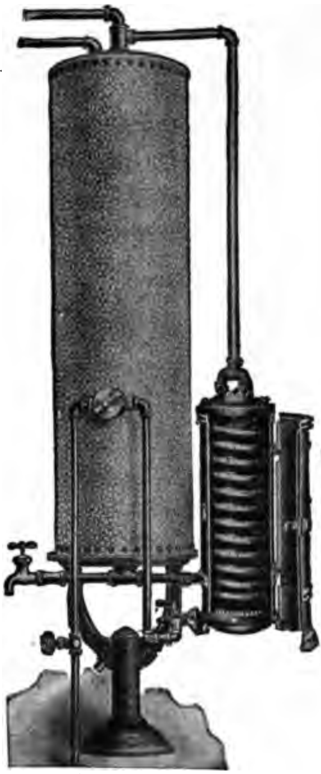


Fig. 90. Crane Gas Heater Connected to Range Boiler Controlled by Thermostatic Valve.

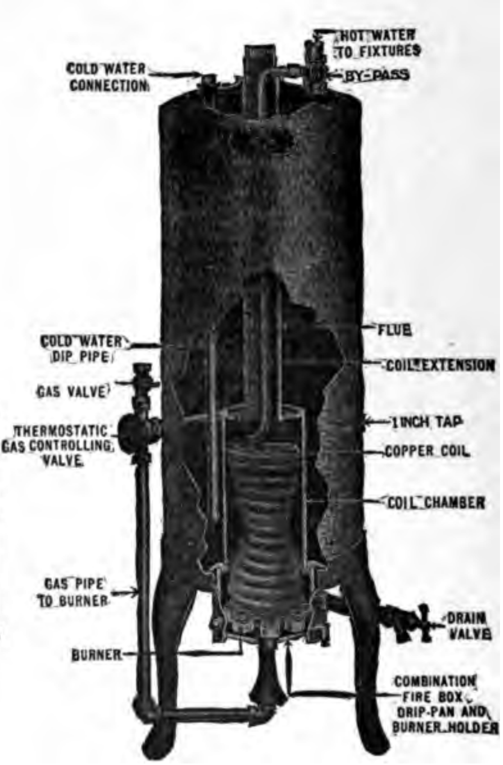


Fig. 91. "Lawson" Combination Gas Heater and Range Boiler Thermostatic Control Valve at Left.

Courtesy of Crane Company, Chicago

Gas Heaters. There are gas heaters provided with thermostatic or pressure mechanism by which the hot service is taken care of automatically. The latter of these are simply connected in the line in a convenient place, and operated by a differential valve. Their appearance is shown in Fig. 89. Simply opening any hot-water faucet reduces the pressure, and the gas is thereby turned on full as long as water is drawn. A pilot light ignites it, and the supply is heated as fast as it passes through the copper coils of the heater. No storage capacity is required by this form. In another form, shown in Fig. 90, the heater is controlled by a thermostatic valve projecting into the regular reservoir used with it. When the water in the reservoir is heated to the desired temperature, the gas supply is reduced or cut off. In Fig. 91 is shown in part section the "Lawson"

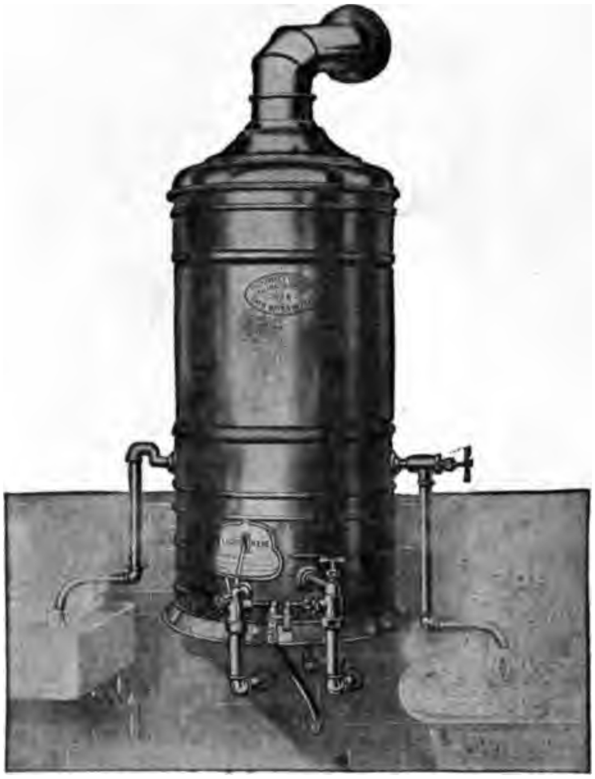


Fig. 92. Instantaneous Gas Heater Connected to Gas Supply Pipe and Operated Directly in Bathroom.
Courtesy of The Humphrey Company, Kalamazoo, Michigan.

combination gas heater and range boiler. This is a very reliable heater and is very well designed. The copper-tube coil forms the direct heating surface, having water connections at both top and bottom of the boiler. The thermostatic valve shown at the left regulates the gas consumption. Drawing water from the hot faucets lowers the temperature in the reservoir through the cooling influence of the incoming water, and the thermostatic principle is again made to serve in opening the gas-valve until the water is heated to the desired temperature.

There are other arrangements consisting essentially of an encased copper coil, above a gas-burner, connected to a standard reservoir at top and bottom. In these, the gas is turned on and regulated by hand as nearly as possible to suit the needs.

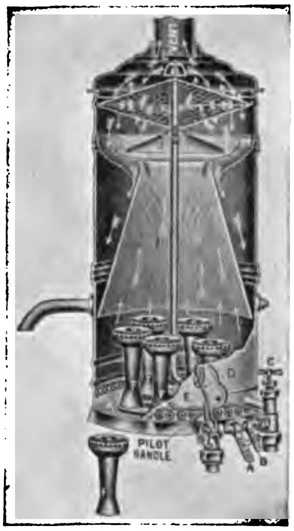


Fig. 93. Sectional View of Humphrey Heater Shown in Fig. 92.

Instantaneous water-heaters, operated by gas or gasoline, and placed in proximity to the fixtures served, as shown in Fig. 92, so as to deliver the heated water directly, are in general use where local conditions favor them. These have no storage capacity. A sectional view of Fig. 92 is shown in Fig. 93. In this heater, the water is not exposed directly to the heated air and gases, and water so heated is suitable for use for any purpose so far as the method of heating is concerned. The purposes for which water heated in contact with the gases of combustion may be used is limited.

Other heaters of this class offer admirable means for the water to take up the heat generated by the gas. All of these special means of heating water—especially those not conforming to the plumber's regular routine—are best understood and judged by a close study of the literature supplied by the makers.

FILTERS

Filters are of two classes. One class is designed to be attached to the end of the faucet or to special connection for drawing directly for use. The other is for use in the general house service, and filters all the water that passes through the main service for whatever purpose. In the former class, sand, free stone, or unglazed potter's clay is used as the filtering medium. Ordinary fillings become foul throughout the mass, and require cleansing or renewing. The clay (unglazed porcelain) of which the Pasteur filter is an example, permits nothing to enter the filtering medium that the pores of this material will strip out. With such, therefore, it is necessary only to remove the tubes and cleanse the surface with which the unfiltered water comes in contact. Any porous filter plate depends for its efficiency upon the minuteness of the pores through which the water passes; and there is a real danger that after a prolonged period of use, these pores may become enlarged by wear from the flowing stream to a size sufficient to allow the passage of bacteria which at the first would have been retained upon the surface of the filter plate. Porous clay filters, however, are exceedingly slow in operation; and it is necessary to employ a multiplicity of tubes, and to collect the filtered water in a reservoir, in order to be able to get enough at once to serve ordinary cooking needs. The filters are supplied with as many tubes as desired, together with the necessary reservoir, all complete excepting connections for the water pipe.

Large filters for service interposition depend upon animal charcoal, beach sand, and coagulating processes—usually the last-mentioned feature in conjunction with one of the other two. A sand filter, for instance, will be made to favor the subsidence of foreign material by the water taking an upward course through the mass of filling, a portion of the water being passed through an alum chamber so as to impregnate the supply sufficient to coagulate impurities which sand alone would allow to pass. When dissolved and carried away, the alum must be replaced. The filling is discarded and new sand put in its place from time to time; and periodic cleansing of the filling is done by reversing the flow of water and flushing out through a waste connection at the bottom. The means of thus keeping the filter in good order are provided for in its construction, in a way to make the cleansing and renewing of the material as easy and convenient as possible.

WATER MOTORS

Water motors for general power purposes, of light nature but requiring comparatively high speed, are made on the rotary plan, a jet impinging on the blades. Others, often used for oscillating fans, operating air-bellows for church organs, etc., have reciprocal motion, the water being handled in a cylinder much as steam is in a reciprocating steam engine. Air-compressors for light duty, operated by water, are made on the reciprocal plan, and also in a way to fill and dump alternately a pair of pivoted buckets, the water pressure expelling the air into an accumulator by filling the bucket with water until it becomes overbalanced, when it falls and trips a waste-valve in the bottom, and at the same time cuts off the supply to one bucket and turns it into the other.

Knowledge of these and kindred devices for producing motion by water-pressure, is not considered a part of the plumber's curriculum; but it is to his interest to learn about them when he can do so without interfering with studies that should take precedence by reason of more immediate importance.

When a pressure tank—the so-called *pneumatic* plan—is used, the supply piping for plumbing fixtures is essentially the same as for street pressure; but when the supply is by gravity, from a tank, new problems present themselves. The type of tank used may in some cases be decided by reasons other than adaptability or simple preference. If of iron, the tank must have a safe-pan to intercept condensation, unless it is insulated from the air, which is difficult and expensive except when the lightness of the metal requires casing for support.

Any shape with flat bottom provides for retaining much sediment that would otherwise flow down with the water. Closed cylindrical tanks, those with merely a pipe-opening to the air, have not even this redeeming feature. Open, rectangular, lead-lined tanks, with loose cover, serve best. An overflow two sizes larger than the supply to tank (never less than 2 inches' diameter) should always be put in near the top. Roof water is sometimes led directly into an attic tank, to avoid pumping. The tank is then divided so that one portion will act as a sort of filter, the water, after subsidence, finding its way into the distributing portion through a screened opening in the partition, some inches above the bottom. This plan requires a large tank, with extraordinary support.

The water is never so well filtered as it may be, if the regular yard cistern with intermediate filter is used; and, all things considered, this is not a plan advisable to follow. The house supply should be taken from a little above the bottom, and well screened to prevent accidental choking. The valve-controlling distribution may be an ordinary stop-cock with an air-pipe carried from immediately below it to above the overflow level, terminating in a position to discharge into the tank, so that air can enter to drain the line; or it may be the regular cistern valve, so arranged, or—which is far better—a hollow stopper valve, with pipe stem extending to above the overflow level, having a chain attached to the stem, and terminating at a convenient point downstairs so that the supply can be stopped at will without going up to the tank. The hollow stem will admit air to the service when the water is off, and there will be no danger of accidental breakage or freezing, as is the case when the necessary relief pipe is carried up outside the tank wall. A standing bath waste fitting can be adapted to admirable service in this capacity; a strainer fitted in the collar of the waste inlet takes the place of the usual screen-hood, and the inlet is just far enough above the bottom to avoid trouble from sediment. The tell-tale pipe should be taken from the bottom of the overflow pipe near the tank, and should discharge where it can easily be observed while pumping is in progress—over the kitchen sink, if the pump is beside the sink. If the closets are to be flushed by valves instead of individual tanks, a separate supply with cut-off should be put in for them.

Pumping into the bottom of the tank, and taking the cold-service branches from the pipe thus used to fill it, should never be practiced. The little difference in head against which the pump must work when pumping over the top, is too small to be considered when compared with the disadvantages of the combined service and pump delivery, even though one line of small pipe is thereby saved. Failure of the single line prohibits service to the fixtures, and pumping into the tank, too; moreover, water that has been pumped is likely to find its way back to the cistern through leaky pump-valves, and there is more trouble in draining both the house pipes and the pump. In placing stop and watse cocks in tank installations, care is necessary to set the right end up, as the water is usually feeding down, instead of up as when direct pressure prevails. Thus, when a cock is set properly, air sometimes enters the waste-hole to cause the line to drain out at some other point—just the reverse of what happens in direct work. However, by bringing the main cold service to the kitchen, and feeding back with the various lines from a manifold, instead of branching out with the cold water on the downward course, the stop-cock work will be about the same as on direct work, after the manifold is reached.

The supplying of hot water to the fixtures should be as direct as possible in all jobs where circulation is desired. Dipping the supply from the top of the reservoir to below the sink level, in order to secure a handy location for the stop-cocks, and ease in taking care of the drain-water, is most certain to interfere with circulation, and not infrequently makes it a matter of impossibility.

The hot-service connection of a tank installation should continue up to and over the tank, as should the main lines of cold service, if convenient, when feeding upward. Also, as there is no street main to give relief, it is good practice to carry a line from the hot-service opening in top of reservoir directly to the tank, and over it, without stop-cocks or branches, so that there will be no ordinary means of closing it. This line will make it impossible to shut off all means of egress for steam and vapor, and may prevent serious accidents otherwise possible.

Tank installations are so often remote from a plumber that every reasonable means should be provided for enabling the users to avoid trouble. A branch from the pump delivery, connecting with the cold service over the reservoir by stop-cock, is permissible, that the reservoir may be filled directly from the pump, by pumping slowly, when the tank or regular supply is out of order. A branch with permanent upright cock-funnel, is often placed on the cold over the reservoir for the same purpose. One may then open the cock, and pour in water with a pail.

The hot service is sometimes brought down from the reservoir, and up behind the sink, for convenience in using the stop-cocks even though circulation is to be employed. In these cases a loop to the attic level is used to induce circulation. Instead of returning from the lavatory or end of the main line, as in other tank jobs and in pressure work, the relief continuation of the hot to the tank is used for the flow of the loop, and a branch is taken from it in the attic and carried back to the bottom pipe of the stove connection. The return of the loop should be larger than the balance—that is, larger than the rising relief from which it is taken. Circulation is dependent upon the difference in temperature of the water in the two lines of the loop; and the large return, by radiation, creates a greater variation of temperature than would be possible in two lines of the same size. It is thus sought to secure sufficient difference in the weight of the two columns to overcome the impediment due to trapping the supply, as stated.

A material auxiliary feature to which success should sometimes be credited in this type of installation, is the skilful arrangement of a tee or Y fitting at the junction with the stove connection. Water being heated in the stove, circulation through the heater is inevitable. To aid the general hot-service circulation, it is then but necessary to divide the work of furnishing water to the heater, between the reservoir connection and the return pipe of the loop. This is done by reducing, at the circulation connection, the flow from the reservoir to the stove, to much less than the capacity of the regular size from that point to the heater. This constriction makes the reservoir feed inadequate to supply the demand of the heater; and the deficit is drawn from the circulation loop, thus keeping the water in motion therein—which is the end in view. If a Y fitting is used, the circulation should attach to the branch, so that its flow will change direction only 45 degrees. If a tee fitting is used, the constriction should be in the branch, and the circulation connected at the end of the tee, so that its flow will not change course at all in joining the feed from the reservoir.

The means of turning the sediment pipe on and off should always be a ground-key cock (especially if connected to the waste) so that one can see at a glance whether it is on or off, as accidental emptying of the reservoir is dangerous. Another reason for using cocks is that the shearing action of the core, when turning, will cut off a piece of lint or other foreign matter that would not permit a compression stop to close tight. Whether a *cock* has closed tight, is not observable; and the whole supply in a tank job may in this way be lost without warning, leaving the heater dry. Unknown waste through the sediment cock retards heating. The failure of hot faucets to close tightly will waste water as fast as it is heated. Hot faucets should have washers adapted to withstand heat, in order to avoid frequent repairing.

Where lime or other deposits choke the water-back and connections as ordinarily installed, both the annoyance and the danger may be avoided by following the plan shown in Fig. 94, in which the water is heated by water by conduction through a coil in the reservoir. The water-back is connected to the coil; and an expansion tank, piped as shown, is provided to take care of the expansion of the water in the primary heater or water-back. Distilled water is used in the back to avoid incrustation of the back and connections. *C* is the tank, which must be filled to above the flow connection. *G* is tank return; *D*, the drain to water-back and connections; *E*, a sediment cock on the reservoir proper. The flow from upper water-back connection to expansion tank should be at least one size less than either the coil in the reservoir or its connections.

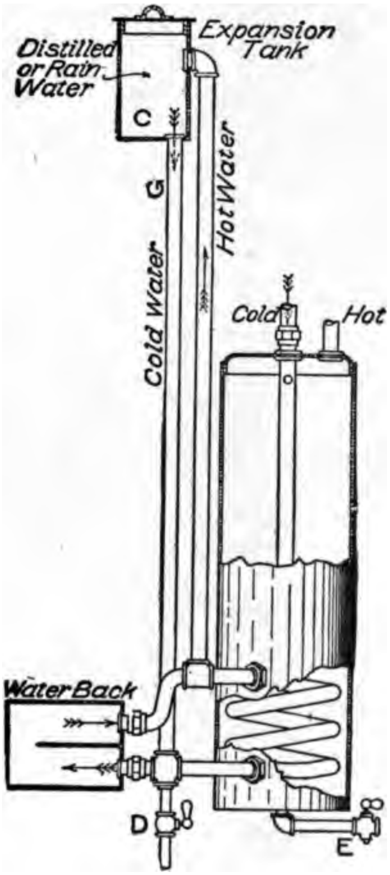


Fig. 94. Reservoir Heated by Hot-Water Coil, Connected to Water-Back, Avoiding Choking from Lime or Other Deposits.

When cost is not the desideratum, direct-pressure plumbing is generally better if a tank is used, even though the initial pressure is ample and not excessive. The pressure on the fixtures is then always constant, and also moderate unless the building is very high. This point is important where the city pressure is sufficient for fire purposes, or when the pressure is carried abnormally high only during the need for fire purposes and then reduced. A high-pressure line feeding the house tank and controlled by a ball-cock, permits valves of simpler mechanism and lighter pipe and fittings, and reduces water-hammer, etc. Moreover, much foreign matter carried in suspension is got rid of, subsidence improving the water and reducing the wear and tear on valves and washers to a minimum.

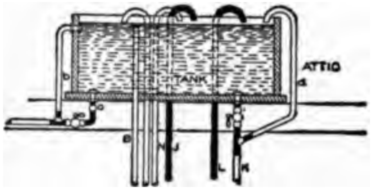


Fig. 95. Essential Connections of a House Tank.

Fig. 95 shows the essential connections of a house tank. *B* is the supply to tank. A ball-cock is used when city pressure supplies the tank; *C* is the drain-pipe, and *B* the overflow. *K* is the cold service to fixtures; and *d* the air-pipe enabling the line to drain when the cock is turned off. The cold-service connection rises above any possible sediment level in the tank. *J*, *L*, *N*, etc., are extensions of the hot and cold fixture lines.

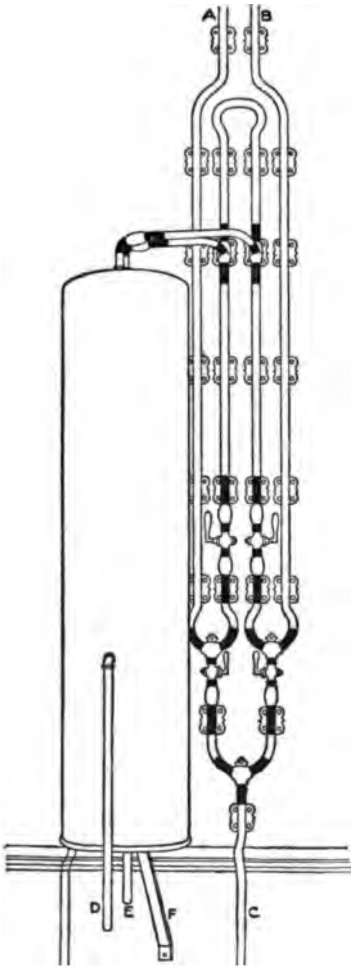


Fig. 96. Distributing Lines of Lead Pipe for a Tank Installation.

Fig. 96 shows the distributing lines of a lead-supply tank installation. *A* is the pipe leading from the tank to the reservoir, the cold for bathroom being branched from it above. *B* is the main hot service. *D* and *E* are range connections. *F* is a brace supporting the ring under the reservoir. The main stops are within reach from the floor. *C* supplies a hall lavatory, and also acts as a drain for the main lines. The arrangement permits supplying either hot or cold water to the little hall lavatory; and a cock at the lowest point in *C* enables the whole combination to drain through it when necessary.

By reason of addition of fixtures, incrustation, or other sufficient cause, supplies sometimes fail to give water rapidly enough. This can be remedied by attaching a closed cylinder, and feeding from it. The pressure will fill the cylinder more or less when water is not being drawn, so that it will flow in abundance when a faucet or valve is opened.

If the regular supply is dropped into a cylinder, a separate feed pipe is necessary. If the fixture line is large enough, the cylinder may be placed at the upper end, and a check-valve below the lowest fixture to retain what enters the cylinder. Then, when a faucet is opened, the cylinder furnishes the water until it is exhausted or the street pressure supplements or overcomes the downward flow.

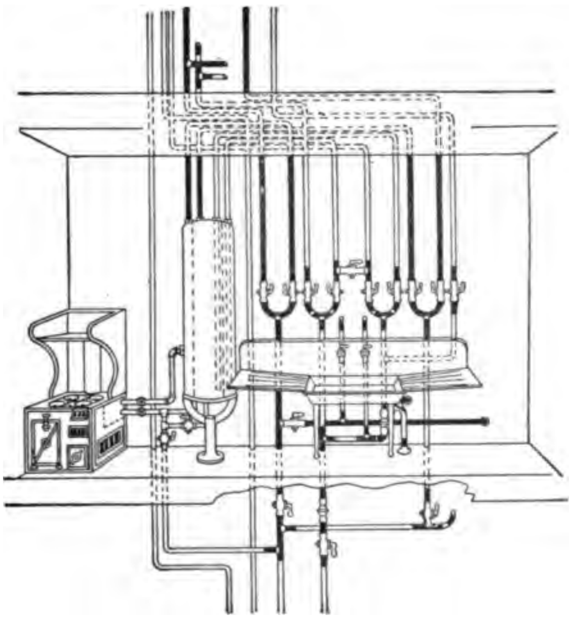


Fig. 97. Double-Reservoir Installation for Heating Combined Direct and Tank Supply. Reservoir Consists of Two Concentric Cylinders, Outer One (Direct) being Connected to Water-Back, and Inner One Heated by Conduction.

Where the street pressure is not sufficient to reach upper floors, trouble is often experienced in pumping to the tank, on account of the service being too small to fill the cylinder of the pump at ordinary speed. This can be overcome by placing a pocket or sort of air-chamber in the service, and connecting the pump suction to it. The influx of water to the pocket is constant, and the suction of the pump intermittent; hence the full, unchecked capacity of the service pipe is available to the pump. The air-chamber feature permits the water to leave the pocket easily. It is proper to place a check-valve on the house side of pump connection, to avoid annoyance from air when faucets used directly are opened.

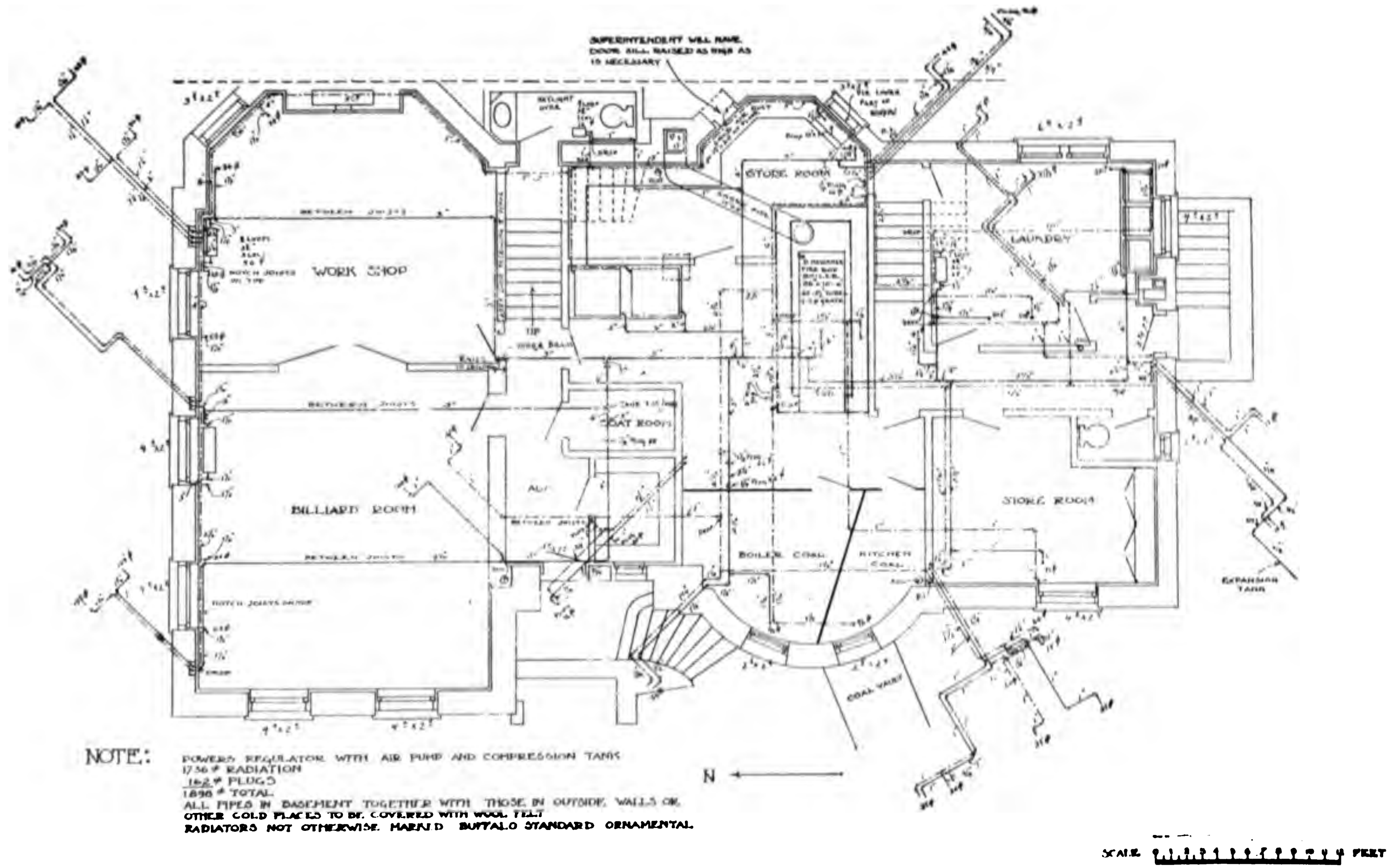
Another problem of inadequate street pressure where part of the house is supplied from a tank, is the heating of the water of both systems. Only large hotel ranges maintain two fires; and there is not ordinarily room for two heaters in one firebox without interfering with the fire or with the baking properties of the cooker; and mixing the supplies is prohibitive. The difficulty has been overcome in two ways. In one, a double reservoir is used, the high pressure (water from the tank) being turned into the inner one, which is concentric with the outer. A job of this kind is illustrated in Fig. 97. The room required for one reservoir is thus saved, and no extra water-back or secondary heat is necessary. One set only of range heater connections are made—to the outer reservoir. The inner reservoir being entirely encased by the water of the outer one, the heating of the water in the inner one is accomplished by conduction only. The range heater might be connected to the inner reservoir; but the surface for conduction would be the same, and much heat, of the limited supply due to conduction, would be radiated from the walls of the outer reservoir. The high pressure might also be connected to the outer reservoir; but greater care in providing against the possibility of the inner one collapsing would be necessary, as it is or should be made of copper. In double-reservoir jobs, a connection, with check-valve, from the street cold to the tank cold, is made at the reservoir. In this way, if the tank should become empty, the street pressure opens the check-valve without attention, and keeps the inner reservoir filled, and of course supplies automatically any fixture on the high-pressure system that the street pressure will reach.

A second plan of heating the water of both systems, also by conduction, is to use two independent reservoirs. The system requiring the greatest amount of hot water is given a direct connection to the heater, and a *secondary heater* for warming the water of the other system by water is interposed in the upper pipe of the connections leading to the firebox. The *secondary heater* has a series of channels or cells, all connecting and pressure-tight and provided with openings for pipe connection. The water of one reservoir is connected to the cell spaces in the secondary heater, just the same as though it were in the firebox; and the water of one system is in that way heated by conduction, by circulating the heated water of the other system about it as it passes from the range heater to its reservoir.

The third method of providing *double-boiler* service is shown in Fig. 98. Referring to the engraving, A is a 1¼-inch pipe, leading directly to the tank, and bending over the top. It is connected to a pump in the basement. B is the main supply from the street, to which pipe A is connected at a lower point. No. 2 is a check-valve placed in the main street supply for the purpose of preventing the pump from drawing water from the street-pressure reservoir while pumping water into the tank in the attic. This might occur for various reasons if a check-valve is not used, and would certainly result in case the pump should be operated while the street supply was shut off. Check-valve No. 2 also prevents the tank water from going into the street pipe when both systems are working under high pressure. In practice, a drain-cock should be placed in pipe B above check No. 2. C is the main cold supply, leading directly from the tank to the kitchen, without branches to fixtures at any point. It connects above check-valve 3 to a pipe leading to the tank-pressure reservoir. From the lower end of check 3, a pipe leads over to the main cold supply B. The superior pressure of the tank system keeps check 3 closed, so that water cannot enter the tank system or reservoir from the street while there is pressure upon it from the tank supply. However, immediately upon the tank becoming empty, or its pressure shut off at cock No. 9, the pressure falls in the tank-system pipes until the pressure is inferior to the street pressure, and check No. 3 opens upward and allows the street pressure to keep the tank-pressure reservoir filled. Otherwise trouble might possibly result, but it is not so probable as in jobs having one reservoir within the other. This check admits of both reservoirs filling without having water in the tank when the job is first started; and although it is a minor point to speak of, it is best to be prepared for accidents.

The main cold supply from the tank is controlled by stop-cock No. 9. Just below the cock a small pipe is branched in, and carried up and curved over the top of the tank, to admit air when it is desired to drain the pipe. D acts as a drain to the hot-water pipes of both reservoirs. The sediment pipes of the reservoirs are also connected to it.

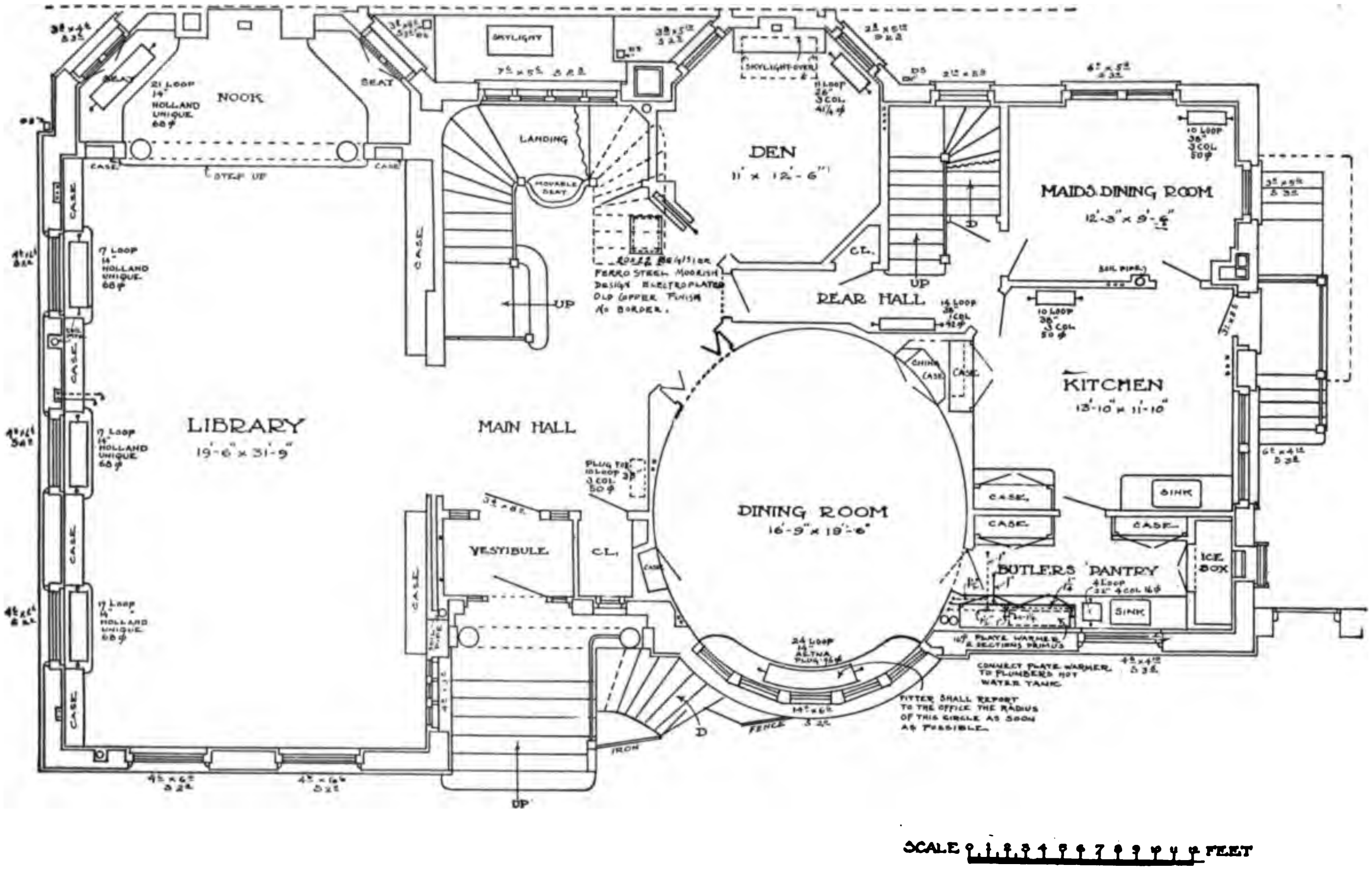
To aid the reader in tracing the different pipes easily, all the hot-water pipes are represented by heavy black lines, and the cold-water pipes by double parallel lines. C^1 is the cold supply to tank-pressure


SUPERINTENDENT WILL HAVE DOOR SILL RAISED AS HIGH AS IS NECESSARY
WORK SHOP
BILLIARD ROOM
STORE ROOM
LAUNDRY
COAL ROOM
BOILER COAL
KITCHEN COAL
COAL VAULT
EXPANSION TANK
N
NOTE: POWERS REGULATOR WITH AIR PUMP AND COMPRESSION TANK
1736 # RADIATION
162 # PLUGS
1898 # TOTAL
ALL PIPES IN BASEMENT TOGETHER WITH THOSE IN OUTSIDE WALLS OR OTHER COLD PLACES TO BE COVERED WITH WOOL FELT
RADIATORS NOT OTHERWISE MARKED BUFFALO STANDARD ORNAMENTAL
SCALE FEET

BASEMENT PLAN OF RESIDENCE OF MRS. JAMES H. BARNARD, CHICAGO

W. Carbys Zimmerman, Architect, Chicago

Plan shows layout of hot-water heating plant. For exteriors and other plans see pages 315, 346 and 363.



NOOK
SEAT
21 LOOP 14" HOLLAND UNIQUE 68#
STEP UP
CASE
SKYLIGHT
LANDING
MOVABLE SEAT
DEN
11' × 12'-6"
SKYLIGHT OVER
CL.
UP
REAR HALL
MAIDS DINING ROOM
12'-3" × 9'-6"
SOIL PIPES
KITCHEN
13'-10" × 11'-10"
SINK
ICE BOX
LIBRARY
19'-6" × 31'-9"
17 LOOP 14" HOLLAND UNIQUE 68#
MAIN HALL
ROSE 8 BEAUSIER FERRO STEEL MOORISH DESIGN ELECTROPLATED OLD COPPER FINISH NO BORDER.
DINING ROOM
16'-9" × 19'-6"
24 LOOP 14" AETNA
VESTIBULE
BUTLERS PANTRY
CHINA CASE
CONNECT PLATE WARMER TO PLUMBERS HOT WATER TANK
FITTER SHALL REPORT TO THE OFFICE THE RADIUS OF THIS CIRCLE AS SOON AS POSSIBLE.
FENCE
IRON
D
UP
SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 FEET

FIRST-STORY PLAN OF RESIDENCE OF MRS. JAMES H. BARNARD, CHICAGO

• W. Carbys Zimmerman, Architect, Chicago

In this plan the radiators are located. For exterior and other plans see pages 315, 346 and 363.

reservoir; C^2, tank supply, cold water, to fixtures on the second and third floors; C^3, cold supply to street pressure reservoir; and C^4, cold supply from street pressure to fixtures on the first floor. *FF* are hot and cold faucets at the kitchen sink, the hot being on the left side. *H* is the main hot supply of the tank system; H^1, hot supply from the tank reservoir to the fixtures on the second and third floors; H^2, main hot supply from the street-pressure reservoir; and H^3, hot supply from the street reservoir to the fixtures on the first floor.

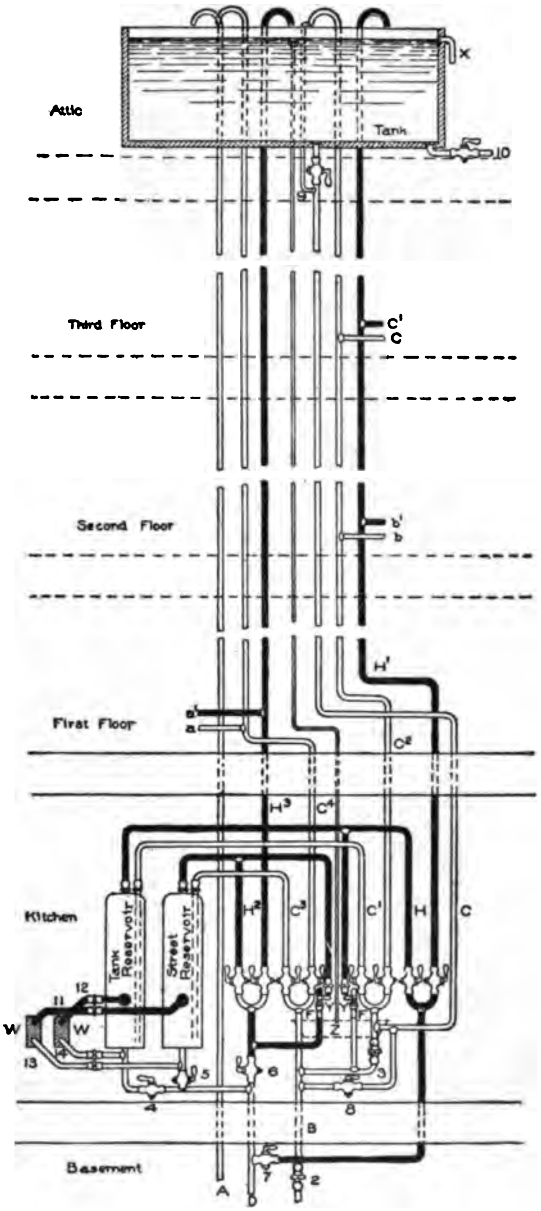


Fig. 98. Double-Reservoir Installation for Heating Combined Direct and Tank Supply. Two Independent Reservoirs, Each Connected to a Water-Back.

It will be noticed that each of the supplies has been carried up as high as the top of the tank, and curved at the end so that they will discharge into it, which, in the case of hot supplies, might occur from steaming. The extension of the fixture supplies to the top of the tank with ends left open, insures that they will drain themselves when the water is shut off; and also cushion the pressure when the faucets are turned off quickly, the same as air-chambers do on direct-pressure systems.

The hot and cold supplies from the street reservoir might be left off at the point where the branches are made on the first floor, without causing any material difference in the working. In that case, however, there would be no vapor relief for the reservoir through the hot-water pipe; and when the cocks were shut off, none of the pipe would drain unless the faucets were opened upstairs. As it is, the main line will drain whether the faucets are open or not; and there is also the advantage of the air-cushion and relief as well.

Of the cocks which are located over the kitchen sink, only those on the pipes leading to fixtures on the upper floors—are stop and waste cocks. The others are plain stops which prevent any chance of causing them to waste continually by some error in using them. Stops and waste would be of little value on the lines above the sink which lead direct to the reservoirs, because it is not particularly desirable to drain any of the pipe between the cocks and the reservoirs while the cocks mentioned are shut off.

The branches aa^1, bb^1, and cc^1, are of $\frac{5}{8}$-inch pipe, and supply fixtures on the first floor from the street pressure, and on the second and third floors from the tank pressure. W and W represent water-backs, both of which are in the same firebox of the range. One of them is connected to the tank reservoir by means of circulating pipes 12 and 14, while the other is connected to the street reservoir by pipes 11 and 13. The sediment pipes of the reservoirs are controlled by cocks 4 and 5. Both of the sediment pipes discharge into the general drain-pipe D. The overflow pipe of the tank is indicated by X. Y and Y are vacuum valves situated over the kitchen sink. They communicate with the reservoirs through branches from the main hot supplies.

By referring to the engraving, the reader will see that there is no way to cut off communication between the reservoirs and the vacuum valves. With the valves placed at the sink as shown, the weight of the water in the vertical pipe above the valves must be overcome before air will enter the reservoirs. If desired, the valves may be placed in the heads of the reservoirs, and a pipe carried over to the sink to take care of the drippings. In this style of double-boiler work, vacuum valves are not so important as they are in systems having one reservoir within the other, because the reservoirs here described work under about the same conditions as those in ordinary single-reservoir jobs. The tell-tale pipe discharges over the kitchen sink, and is indicated by *Z*. Cock 6 is to drain the hot-water pipe from the street reservoir, and cock 7 drains the hot pipe from the tank reservoir.

Cock 8 is placed in a connection where, when turned on, it allows the tank pressure to by-pass check valve No. 3. By this means, both systems may be worked under high-pressure duty when the street pressure is off. In a case where the street pressure is constant for the fixtures on the first floor, but does not reach the second, cock 8 will seldom have to be used, and it should then be of a type having a removable handle.

One point gained by bringing the pipes down and up, as shown by the loops over the sink, is, that every stop can be reached from the floor without the aid of a ladder. The fixtures on the upper floors can be shut off without interfering with the supply to kitchen sink or other fixtures that may happen to be on the lower floors.

The sizes of the pipes shown in this installation, which have not already been given, are as follows: *B* and *C*, $\frac{3}{4}$-inch; C^1, C^2, C^3, C^4, $\frac{5}{8}$-inch; *D*, $\frac{3}{4}$-inch; *FF*, $\frac{5}{8}$-inch; *H*, H^1, H^2, H^3, $\frac{5}{8}$-inch; *X*, $1\frac{1}{2}$-inch; *YY*, $\frac{1}{2}$-inch; *Z*, $\frac{3}{8}$-inch; 11 and 12, 1-inch; 13 and 14, $\frac{3}{4}$-inch. Cocks 4 and 5 are $\frac{3}{4}$-inch; 6, 7, and 8, $\frac{5}{8}$-inch; and 10, $1\frac{1}{4}$-inch.

Plumbers habitually having this type of work to contend with—New Yorkers, for instance—become ultra-skilful in meeting the difficulties presented by variable pressure. The range of variation may cover the second floor of one building and the third of another, according to elevation. The fixtures on the floor with intermittent street supply can be placed wholly on the tank system, only at the expense of pumping all the water used in them. To take advantage of the street pressure reaching those fixtures at certain hours, four cocks are arranged so that one handle will turn all of them at once—two closing the tank hot and cold supply from the fixtures on that floor, and two admitting instead the street-pressure hot and cold.

There are many interesting features in piping water for municipal service, but it is not in the province of this work to consider them.

GAS PIPING

Pipes and Governors. Gas piping is so closely allied to plumbing, since iron pipe has come into general use, that a brief notice of this branch is not out of place in connection with matters pertaining to plumbing. Coal gas is only about one-half the specific weight of air. The weight of natural gas is somewhat less than that of coal gas. The distribution of pressures which prevails in a closed system—the pressure of the fluid due to applied pressure being equal at every point—should not be lost sight of in considering the ordinary method of distributing gas over a city or through a building in closed pipes.

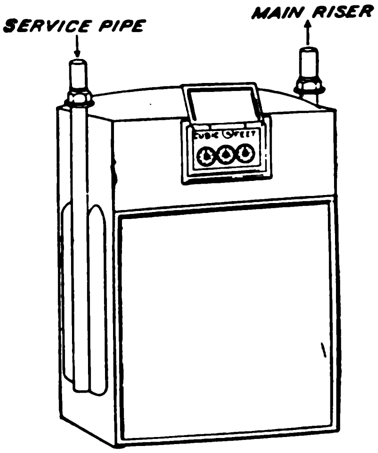


Fig. 99. "Dry" Gas Meter.

Pressures. The most economical pressure at which to consume gas is five-tenths of an inch water pressure. As no town is strictly level, and the friction of the pipe requires some head of pressure to overcome it, the pressure in the mains is necessarily carried above the point at which the best results are obtained. This is generally counteracted by not turning on the full amount at the burner. In towns varying greatly in the level of different portions, it is economy to use automatic governors to control the pressure of the gas in the mains to different levels. This is also true of exceedingly tall buildings in cities whose areas maintain about the same level. One governor for a modern office building is not enough unless the building stands at a low level, in which case the supply to the upper floors may be controlled by one governor situated on one of the upper floors, say midway between the top floor and the average street level.

Gas Meters. Large pipe should not be notched into joists in the middle; it weakens the joists. All pipes should be laid with a decline, toward the meter when possible, otherwise in such a way that they will drain toward a fixture or drip. The meter should be placed in a position easily accessible, and where it may be read without the use of an artificial light. It is connected in the house main on the street side of the first branch. A *dry* meter—the kind now almost universally employed—is shown in Fig. 99.

Different meters vary but little in the arrangement of the dials. In large meters, there are as many as five or more dials; but those used for dwelling houses usually have but three. Fig. 100 shows the common form of index in a dry meter. The small index hand *D*, on the upper dial, is not taken into consideration when reading the meter, but is used merely for testing. The three dials, which record the consumption of gas, are marked *A*, *B*, and *C*; and in each, a complete revolution of the index hand denotes 1,000, 10,000, and 100,000 cubic feet, respectively. The index hands do not move in the same direction. When the hands are pointing upward, *A* and *C* move from left to right, while *B* moves in the opposite direction. Annex two cyphers at the right of the figures indicated when taking the statement of a meter. The left-hand index shown in Fig 100 reads 48,700. Suppose, after being used for a time, the hands should have the positions shown in the right-hand dial. This would read 64,900; and the amount of gas used during the interval would equal the difference in the readings: 64,900 — 48,700 = 16,200 cubic feet. Meters so invariably register in favor of the consumer after being in use only a few weeks, that the companies are by law permitted to set them 3 per cent fast when new.

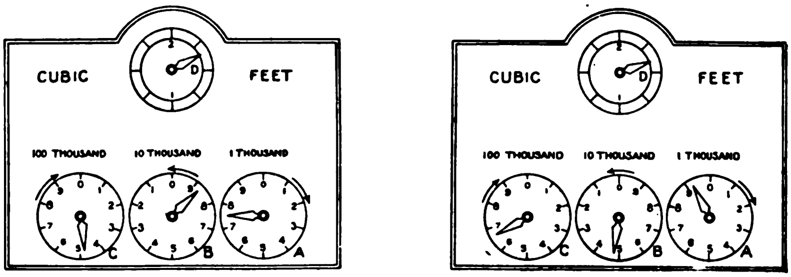


Fig. 100. Common Form of Index on "Dry" Gas Meter. Two Readings are Shown.

The route chosen for gas pipes should be the warmest consistent with convenience and economy. Coal gas will freeze—that is, the moisture in it will, in severe weather, form a network of frost that checks or stops the flow. Coal gas and natural gas are practically fixed. There is little trouble from condensation, even from coal gas, after it reaches the residence. There is sufficient reason, however, to incline the pipe and to avoid trapping any portion so that it will not drain. If a pipe runs through a cold place, a drip should be put in at some convenient point where it can be emptied if necessary. No offsets should be made in a way to favor choking the pipe by the products of corrosion falling down vertical parts. No fixture or bracket opening should be less than ⅜-inch; no rising main less than ¾-inch. All openings for fixtures should have straight threads, and the pipe or fittings should be well secured, perpendicular to the wall passed through, so that they will not wobble, push in, or pull out. Ceiling drops should be cemented in the joint at the line, so that they will not unscrew when the cap is removed or a fixture taken down.

The making of intelligent working diagrams for gas or water fitting, is not difficult. Though important, comparatively few have given it due attention. When plans are accurate, the usual work of making figures to show what length the pipes are, may be dispensed with by employing self-measuring ruled sheets in conjunction with the method of diagramming here described. Diagramming systematically and with all lines approximately proportional in length, saves time in distributing the pipe. There is no wondering whether a piece runs down or up, or as to which room a bracket light looks into, or whether a piece of pipe belongs in a horizontal or in a vertical position. A properly made diagram indicates these points clearly, and also what pieces belong in the same plane. There should never be any confusion as to which pieces have been cut and which not, when getting out the pipe. Symbols can be made to show what pieces have been cut and what size they are. The symbols found by practice to answer this purpose best, are as follows: When a ¼-inch piece is cut, a common check mark is put *beside* the line on the diagram, showing that it is ¼ inch and has been cut. For a ⅜-inch piece, a short, straight mark like the letter I, placed *across* the line, is used. For a ½-inch piece, two connected marks like V are made *across* the line. For ¾-inch pieces, three connected marks, like the capital N, are made *across* the line. For 1-inch pieces, four connected marks, like the capital letter M, are used *across* the line. For 1¼-inch

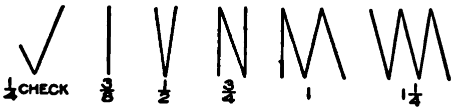


Fig. 101. Symbols Used in Piping Diagrams.

pieces, five connected marks, like the capital W with one extra leg, are used. Each short, straight mark represents a quarter-inch in the diameter of the pipe, except in the case of ⅜-inch pipe. For nipples that are too short to put the symbols on, draw a waved arrow from the nipple, and put the symbol upon it. Fig. 101 shows the symbols described, with corresponding sizes of pipe marked beneath them.

In reading plans of buildings, it is usual to have the front of the building, as represented by the plans, next to the person. Plans represent horizontal sections at the elevations designated; while elevations show the altitude of one floor above the other, etc. The plans of the different floors of a building are usually drawn side by side, with the outside face of the front wall on a line. By this means, a straight edge laid across the plans from side to side, will show which partitions are in line with one another. One can judge with the eye, on the cross-partitions, accurately enough to give a good idea of the relative position of the rooms on different floors, one way; but to locate the partitions running from front to back, it is necessary to measure from the wall on the plans of the different floors. House plans are almost always drawn to ¼-inch scale. In gasfitting diagrams, all sizes of pipe are represented by single or skeleton lines, because the pipes are small.

Now, assuming the plans to be marked for gas, center the rooms, and chalk all wall openings. Then proceed to diagram the lines representing the pipe, making them as nearly proportional to the length of pipe as can easily be done with pocket-rule and pencil, say to ¼-inch scale.

Represent all vertical pipes by diagonal lines parallel to one another, whether they be bracket pipes, risers, or offsets in the line. Never represent a horizontal pipe by a diagonal line. Every vertical pipe which *falls below* the horizontal pipe to which it is connected, should be drawn *toward the front* of the plan at an angle of 45 degrees to the *left*. Every vertical pipe which *rises above* the horizontal pipe to which it is connected, should be drawn *away from the front* of the plan, at an angle of 45 degrees to the *right*. Represent all horizontal pipes by parallel lines perpendicular either to front or to side wall. When the run of pipe is from front to back, the parallel lines should be perpendicular to the front wall of the building. When the run is from side to side, the parallel lines should be perpendicular to the side wall of the building. Any line in the diagram that is perpendicular to any other line of the diagram may then be taken to represent a horizontal pipe. Any number of lines representing horizontal pipe and all joined together, are thus indicated to be in the same horizontal plane. Any single line or system of lines representing horizontal pipe, but separated from the others by a diagonal line, is therefore in a different horizontal plane. For instance, the second-floor riser, 10 feet 3 inches long, shown in the diagram, Fig. 102, connects the horizontal pipe under the second floor with that under the third floor. These pipes are in different planes, one set being 10 feet 3 inches above the other.

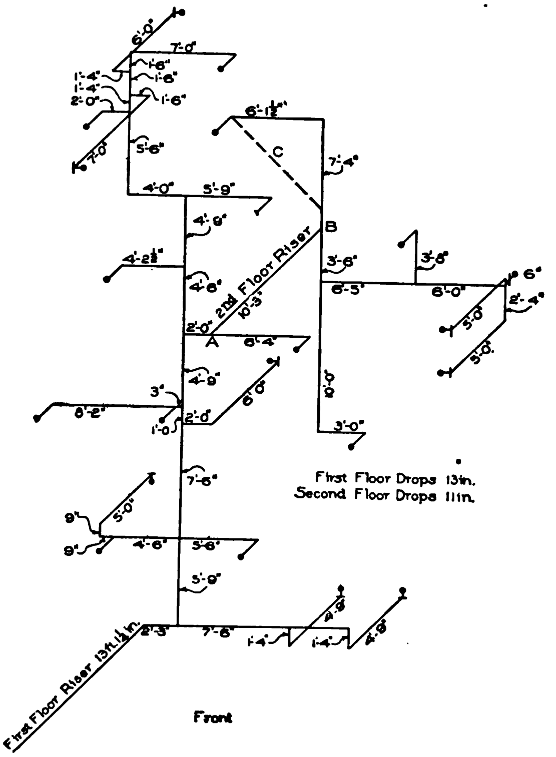


Fig. 102. Diagram of Gaspipe Lines.

There is one exception to the rule concerning diagonal lines. Several feet of pipe can often be saved by cutting across, instead of making an angle with, the pipe. To do this without danger of confusing one as to whether the diagonal piece is intended for vertical pipe or for a diagonal piece in the horizontal plane, make such lines *dotted* instead of *solid*, as shown at *C*, Fig. 102.

To indicate the direction in which bracket openings look, by the way in which they are drawn, eight skeleton diagrams of bracket pipes, showing how the direction of bracket openings would be indicated for the four walls of a square room, are shown in Fig. 103. *A*, *B*, *C*, and

D show that the pipes are vertical and run up from the floor below, *A* looking into the room from the front wall, *B* from the rear, *C* from the left side wall, and *D* from the right side wall. In accordance with plan drawing, the short lines representing the ears and nozzle of the drop-ells are made in plan position with dots at the ends to represent caps. The ears of the fitting, drawn in front of the outlet, show that the fitting looks to the rear; ears behind the outlet show that it looks to the front; at the left of it, that it looks to the right; and to the right of it, that the fitting looks to the left.

A^1, B^1, C^1, and D^1 show fittings that look in the same direction as those shown by *A*, *B*, *C*, *D* of the same figure, but are on pipes that run down from the horizontal pipe. By varying the positions of the marks representing the drop fittings to suit, the diagram can be made to indicate openings pointing in any direction desired.

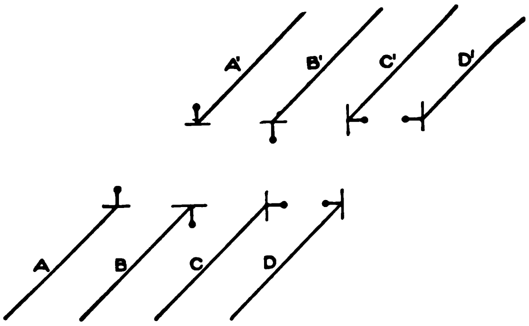


Fig. 103. Skeleton Diagrams of Bracket Pipes.

All large risers should be exposed to view; and it is desirable to keep all piping accessible as far as possible, so that it may be easily reached for repairs if necessary. When it is necessary to trap a pipe, a drip with a drain-cock must be put in; but this should always be avoided under floors or in other inaccessible places. Where possible, it is better to carry up a main riser near the center of the building, as the distributing pipes will then average smaller, the timbers will not require so much cutting, and the flow of gas will be more uniform throughout.

Unless otherwise directed, outlets for brackets should be placed 5½ feet from the floor, except in the case of hallways and bathrooms, where it is customary to place them 6 feet or more from the floor. Upright pipes should be plumb, so that nipples which project through the walls will be level; the nipples should not project more than ¾ inch from the face of the plastering. Laths and plaster together are usually about ¾ inch thick, so that the nipples should project about 1½ inches from the face of the studding. *Drop-* or *side-ells* are used where possible for bracket openings. Gas pipes should never be placed on the bottom of floor timbers that are to be lathed and plastered, because they are inaccessible in case of leakage or alterations. Fig. 104 illustrates some lines of gaspipe in a frame building, from which may be gleaned graphic ideas of how to fasten pipe securely in place.

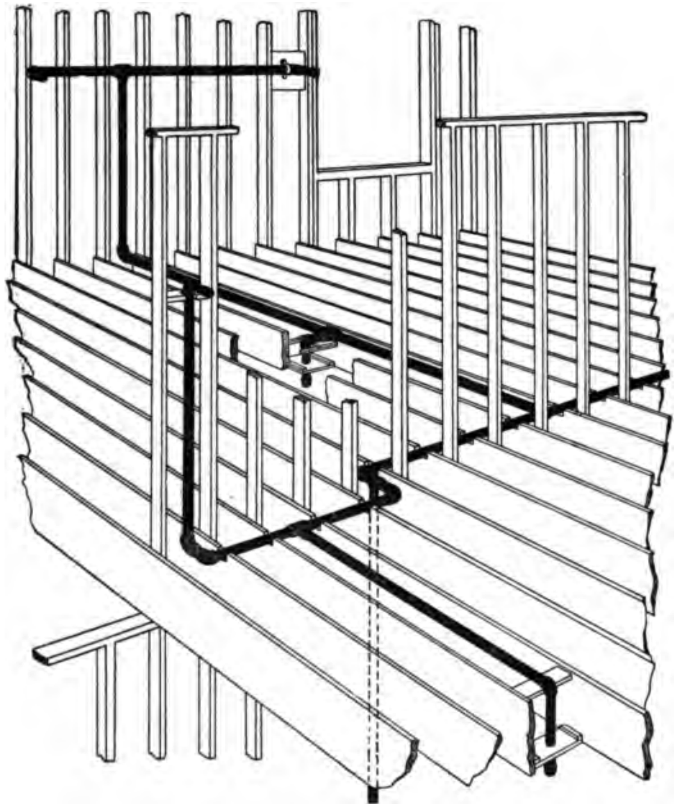


Fig. 104. Lines of Gaspipe in Frame Building, Showing How Pipes are Secured in Place.

Coal gas, and natural gas of some locations, has a strong odor that betrays leakage. Some natural gas is devoid of odor, in which case leakage is very dangerous, as there is no way quickly to detect its presence. For natural gas work, 10 pounds' air-pressure should fail to develop the slightest leak in the pipe, although the street pressure is usually even less than eight ounces. For lighting gas, the street pressure is seldom over 18 tenths water-pressure, and a 5-pound test is ample. These tests should be made with a mercury gauge, 2 inches height of column being considered as one pound pressure. A job may be considered tight when the mercury column not only does not drop, but does not even get flat at the top in from fifteen to twenty minutes' trial.

Every gas company has rules as to the number of lights allowed to be supplied from each size pipe, and the relative lengths of pipe permitted of each size. The following table gives sizes of gas pipes for different numbers of burners and lengths of runs, as usually installed:

TABLE IV

Maximum Run and Number of Burners for Gas Pipes

SIZE OF PIPE	GREATEST LENGTH OF RUN, FEET	GREATEST NUMBER OF BURNERS TO BE SUPPLIED
3/8 inch	20 feet	2
1/2 "	30 "	4
3/4 "	50 "	15
1 "	70 "	25
1 1/4 inches	100 "	40
1 1/2 "	150 "	70
2 "	200 "	140
2 1/2 "	300 "	225
3 "	400 "	300
4 "	500 "	500

No restrictions are observed in selecting fixtures for coal or natural gas. Coal gas carries enough carbon with it to produce a lighting flame when burned at the ordinary flame temperature. When the jet is lighted, the hydrogen is consumed in the lower part of the flame, producing sufficient heat to render incandescent the minute particles of carbon carried by it. The hydrogen, in the process of combustion, combines with the oxygen of the air, forming an invisible vapor of water, while the carbon unites with the oxygen, forming carbonic acid, or is set free as soot.

Various causes tend to render combustion incomplete. There may be excessive pressure of gas, lack of air, or defective burners. An excess of pressure at the burners causes a reduction of the amount of illumination; on the other hand, if the pressure is insufficient, the heat of the flame will not raise the carbon to a white heat, and the result will be a smoky flame. It therefore follows that for every burner there is a certain pressure (usually $\frac{5}{10}$ of an inch water-pressure before mentioned) and a certain corresponding flow of gas, which will cause the brightest illumination.

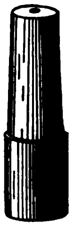


Fig. 105. Single-Jet Burner.

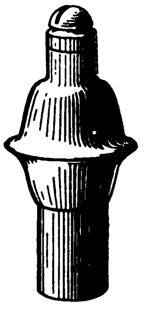


Fig. 106. Bat's-Wing or Slit Burner.

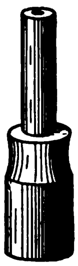


Fig. 107. Union-Jet or Fish-Tail Burner.

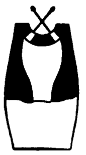


Fig. 108. Vertical Section of Union-Jet Burner.

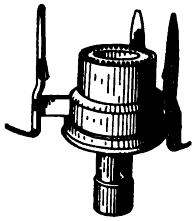


Fig. 109. Argand Burner.

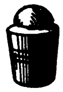


Fig. 110. Lava Tip for Bat's-Wing Burner.

Burners. Many types of burners are on the market, among which the single-jet, bat's-wing, fish-tail, Argand, regenerative, and incandescent burners are the principal types.

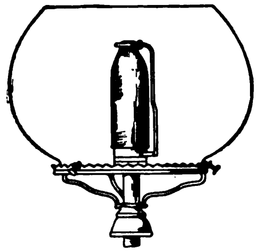


Fig. 111. Gas Burner with Globe and Incandescent Mantle.

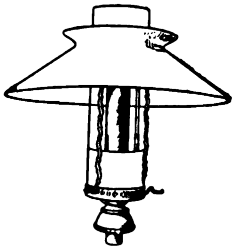


Fig. 112. Mantle Burner with Chimney and Shade.

The *single-jet* burner, Fig. 105, is the simplest kind, having but one small hole from which the gas issues. It is suitable only where a very small flame is required.

The *bat's-wing* or *slit* burner, Fig. 106, has a hemispherical tip with a narrow vertical slit from which the gas spreads out in a thin, flat sheet, giving a wide and rather low flame resembling in shape the wing of a bat, from which it is named.

The *union-jet* or *fish-tail* burner, Fig. 107, consists of a flat tip slightly depressed or concaved in the center, with two small holes drilled, as shown in Fig 108. Two jets of equal size issue from these holes, and, by impinging upon each other, produce, at right angles to the alignment of the holes, a flat flame longer and narrower in shape than the bat's-wing, and not unlike the tail of a fish. Neither of these burners requires a chimney, but the flames are usually encased with glass globes. They are not well suited for use with globes, however, since when one of the jets becomes choked, as it frequently does, the other is likely to crack the glass.

The *Argand* burner, Fig. 109, consists of a hollow ring of metal or lava, connected with the gas tube, and perforated on its upper surface with a series of fine holes, from which the gas issues, forming a round flame. This burner requires a glass or mica chimney. As an intense heat of combustion tends to increase the brilliancy of the flame, it is desirable that the burner tips shall be of a material that will cool the flame as little as possible. On this account, metal tips are inferior to those made of some non-conducting material, such as lava, adamant, enamel, etc. Metal tips are also objectionable because they corrode rapidly, and thus obstruct the passage of the gas. Fig. 110 shows a lava tip for a bat's-wing burner. Burner tips should be cleaned occasionally, but care should be taken not to enlarge the holes.

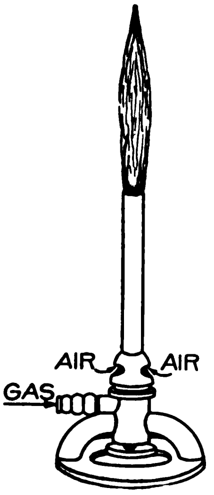


Fig. 113. A Bunsen Burner.

By introducing the Bunsen principle, *incandescent* burners give good service with coal gas. In the incandescent burner, the heat of the flame is applied in raising to incandescence some foreign material, such as a basket of magnesium or platinum wires, or a funnel-shaped asbestos wick, or a mantle treated with sulphate of zirconium and other chemical compounds. A burner of this kind is shown in Fig. 111, in which the mantle can be seen supported over the gas flame by a wire at the side. Fig. 112 shows another form of this burner, in which a chimney and shade are used in place of a globe. Burners of this kind give a very brilliant white light when used with natural or water gas. Natural gases and the so-called water gas are deficient in carbon; and, when they are used for lighting

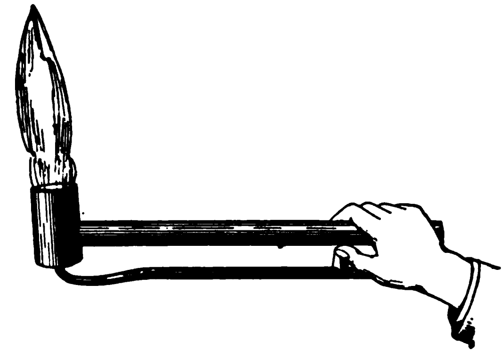


Fig. 114. Gas Burner for Brazing.

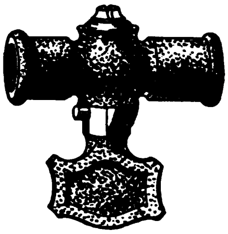


Fig. 115. Single Gas-Cock with Stop-Pin.

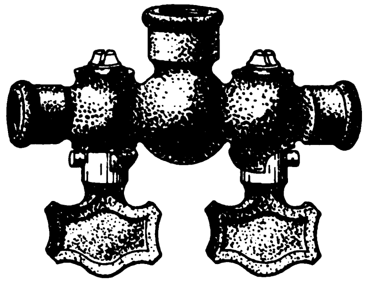


Fig. 116. Double Gas-Cock with Stop-Pins.

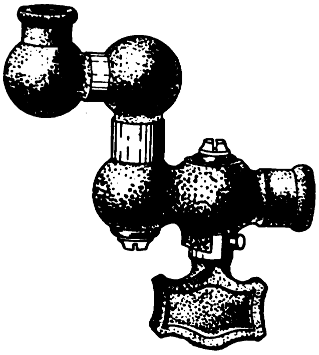


Fig. 117. Elbow Gas-Cock with Stop-Pin.

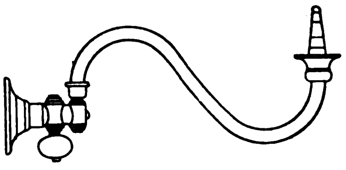


Fig. 118. Common Form of Gas-Bracket.

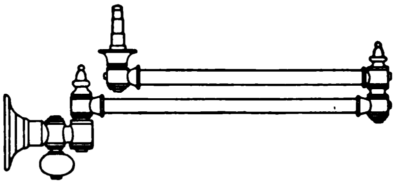


Fig. 119. Two-Swing Extension Gas-Bracket.

purposes, the light is produced by a burner with a mantle brought to a state of incandescence by the heat of the flame. The mantle, however, is very fragile, and is likely to lose its property of incandescence when exposed to an atmosphere containing much dust.

The *Bunsen burner*, shown in Fig. 113, is a form much used for laboratory work. It burns with a bluish flame, and gives an intense heat without smoke or soot. The gas, before ignition, is mixed with a certain quantity of air, the proportions of gas and air being regulated by the thumb-screw at the bottom, and by screwing the outer tube up or down, thus admitting a greater or less quantity of air at the openings indicated by the arrows. This same principle is utilized in a burner for brazing, the general form of which is shown in Fig. 114. A flame of this kind will easily melt brass in the open air.

Fixtures. It is important that gas keys on fixtures should be perfectly tight. It is rare to find a house piped for gas where the pressure test could be successfully applied without first removing the fixtures, as the joints of folding brackets, extension pendants, stopcocks, etc., are usually found to leak more than the piping. The old-fashioned all-around cock without check-pin should never be allowed under any conditions; only those provided with stop-pins are safe. Various forms of cocks with stop-pins are shown in Figs. 115, 116, and 117. All key joints should be examined and tightened up occasionally to prevent them becoming seriously loose and leaky.

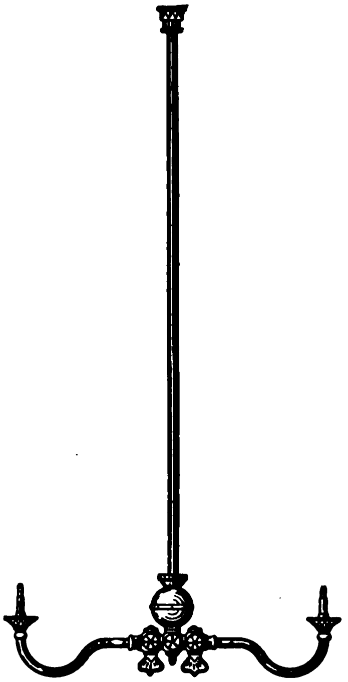


Fig. 120. Plain Type of Two-Burner Gasolier.

Poor illumination is frequently caused by ill-designed or poorly constructed brackets or gasoliers. Gas fixtures, almost without exception, are designed solely from an artistic standpoint, without due regard to the proper conditions for obtaining the best illumination.

Fixtures having too many scrolls or spirals may, in the case of imperfectly purified gas, accumulate a large amount of a tarry deposit, which, in time, hardens and obstructs the passages. Another fault is the use of very small tubing for the fixtures. Common forms of brackets are shown in Figs. 118 and 119, the latter being a *two-swing extension bracket.*

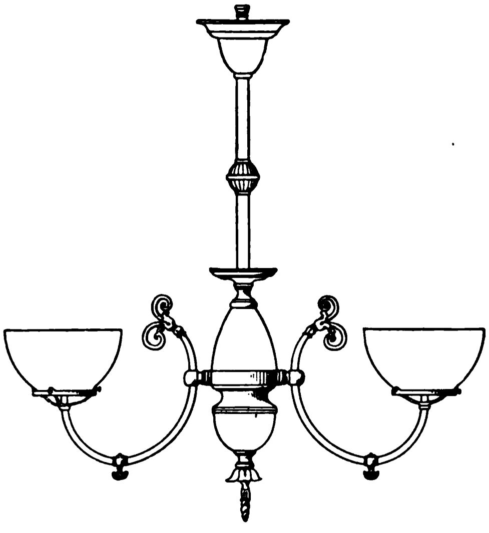


Fig. 121. Ornamental Type of Two-Burner Gasolier.

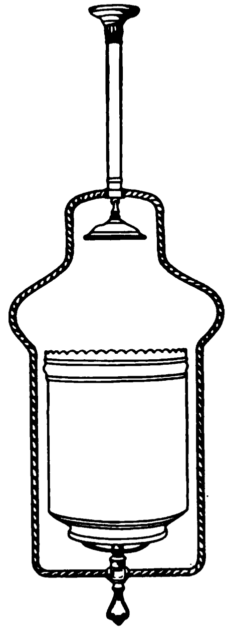


Fig. 122. Gasolier for Hall or Corridor.

There are an endless variety of gasoliers used, depending upon the kind of building, the finish of the room, and the number of lights required. Figs. 120, 121, and 122 show common forms for dwelling houses the type shown in Fig. 122 being used for halls and corridors. The keys should be at the lowest point, as in Figs. 121 and 122, to facilitate removing any condensation that may take place and find its way to the fixture.

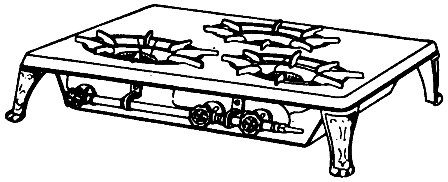
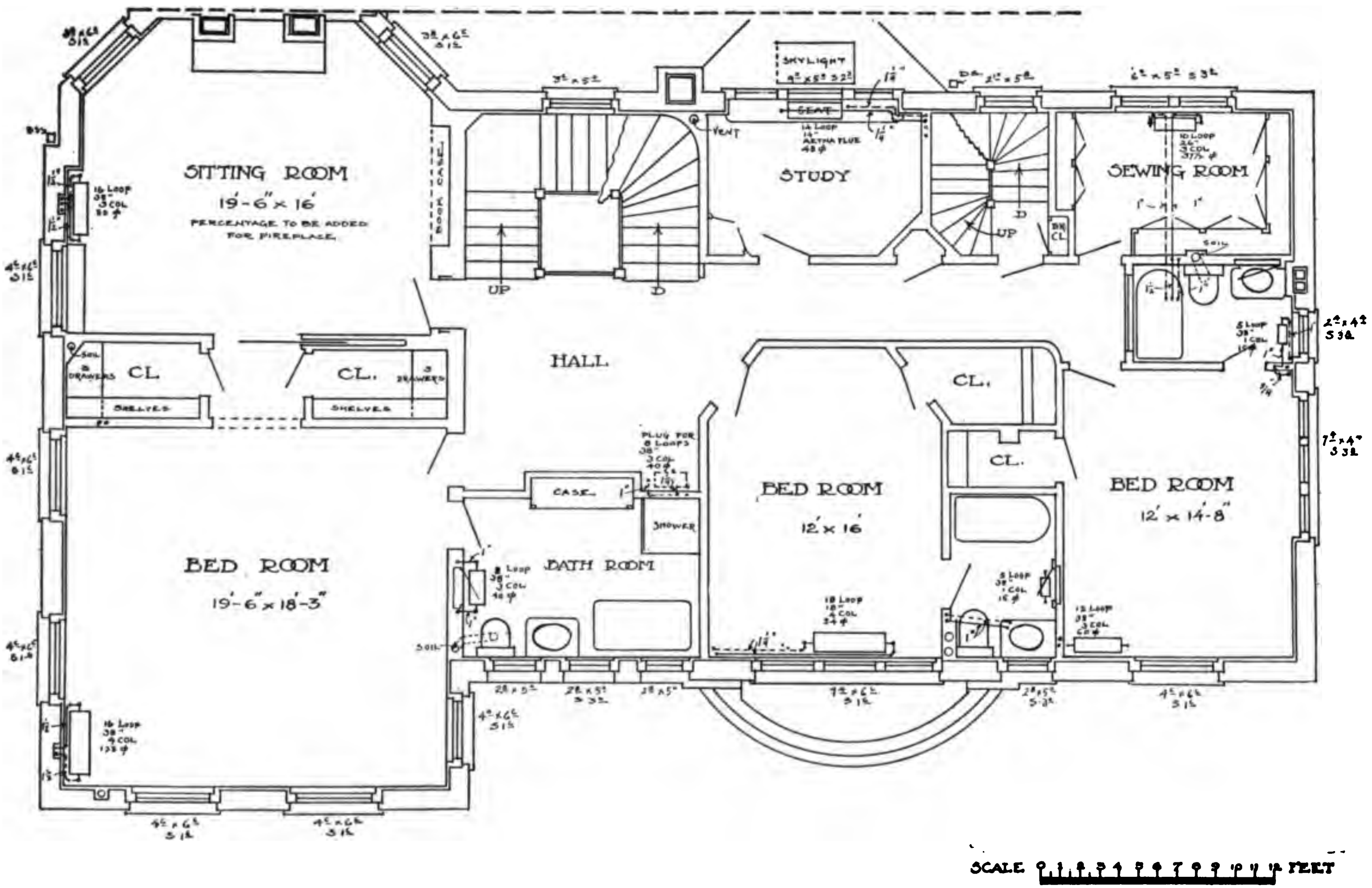


Fig. 123. Simple Form of Gas Plate with Three Burners.



SECOND-STORY PLAN OF RESIDENCE OF MRS. JAMES H. BARNARD, CHICAGO

W. Carbys Zimmerman, Architect, Chicago

For exteriors and other plans see pages 315, 330 and 363.

Next to the burner, the shape of the globe or shade surrounding the flame affects the illuminating power of the light. In order to obtain the best results, the flow of air to the flame must be steady and uniform. Where the air supply is insufficient, the flame is likely to smoke; on the other hand, too strong a current of air causes the light to flicker and become dim through cooling.

Globes with openings too small at the bottom, should not be used. Four inches at the bottom should be the smallest opening used for an ordinary size burner. All glass globes absorb more or less light, the loss varying from 10 per cent for clear glass, to 70 per cent or more for opal, ground, colored, or painted globes. Clear glass is therefore much more economical, although, where softness of light is especially desired, the use of opal or ground globes is made necessary.

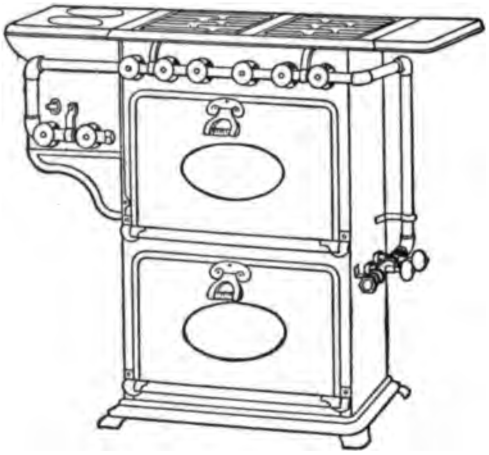


Fig. 124. Gas Range for Family Use, with Ovens and Water-Heater.

Illumination. Illumination is a subject so broad and complex that a fairly thorough consideration of light distribution for different purposes would alone require a volume. A few pertinent remarks tending to aid in approximating the location and power of lamps so as to get reasonably accurate results in ordinary work will not, however, be out of place here.

The unit of illumination is the candle-foot—the power of one standard candle at a distance of one foot from its flame. The intensity of illumination varies inversely as the square of the distance from the source. Therefore we see that one candle-power at one foot from the source gives only one-fourth of a candle-power over an equal amount of surface placed two feet from the source.

The candle-foot illumination of any point, for any bare light nominated can be approximated by squaring the distance from burner to the point selected, using the square as a denominator and 1 as the numerator of a common fraction (reduced to a decimal if preferred) multiplying by the candle-power of the burner to be used and then adding the illumination due to reflection. The result will be near the candle-feet illumination at the selected point.

The reflecting power of wall surfaces may be taken as follows: White paper, .80; chrome yellow, .60; orange, .50; yellow wall paper, .40; light pink, .36; light blue, .25; green, .18; dark brown, .13. The average light wall finish may be taken as reflecting 50 per cent of the light that falls upon it.

From 2 to 7 square feet of floor is allowed per candle-power for ordinary lighting, according to the purpose of the room. The greater spaces are assigned to bedrooms, servants' rooms, etc. The lesser, to dining rooms, billiard rooms, libraries, etc., where higher candle-power is more necessary, the location of the lights being made, as far as practicable, to favor the high intensities required at particular points.

Gas Ranges and Heating Stoves. Cooking as well as heating by gas is now very common, and there are a great variety of appliances for the use of gas in this way. Cooking by gas is not more expensive, and is less troublesome, than by coal, oil, or wood. It is also more healthful, on account of the absence of waste heat, smoke, and dust. A gas range is always ready for use, and is instantly lighted by applying a match to the burner. The fire, when kindled, is at once capable of doing its full work; it is easily regulated, and can be shut off the moment one is through with it, so that, if properly managed, there is no waste as is the case with other fuel. With gas, the kitchen can be kept comparatively cool and comfortable in summer.

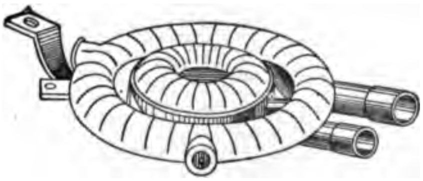


Fig. 125. Griddle Burner for Gas Range.

Fig. 126. Oven Burner for Gas Range.

Gas stoves are made in all sizes, from the simple form shown in Fig. 123, to the most elaborate range for hotel use. A range for family use, with ovens and water-heater, is shown in Fig. 124. Figs. 125 and 126 show the forms of burners used for cooking, the former being a *griddle burner*, and the latter an *oven burner*.

A *broiler* is shown in Fig. 127; the sides are lined with asbestos, and the gas is introduced through a large number of small openings. The asbestos becomes heated, and the effect is about the same as a charcoal fire upon both sides.

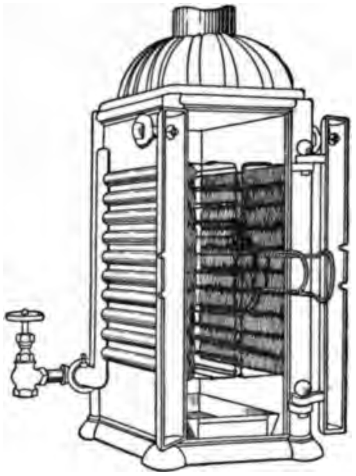


Fig. 127. Gas Broiler, Asbestos-Lined.

Artificial gas as a fuel has not been used to any great extent for the warming of whole buildings, its application being usually confined to the heating of single rooms. Unlike cooking by gas, a gas

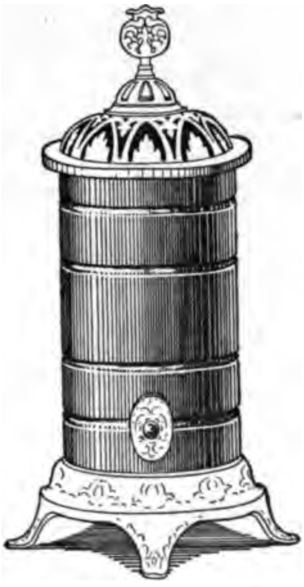


Fig. 128. Common Form of Portable Heater, Connected by Rubber Tubing to Gas-Jet.

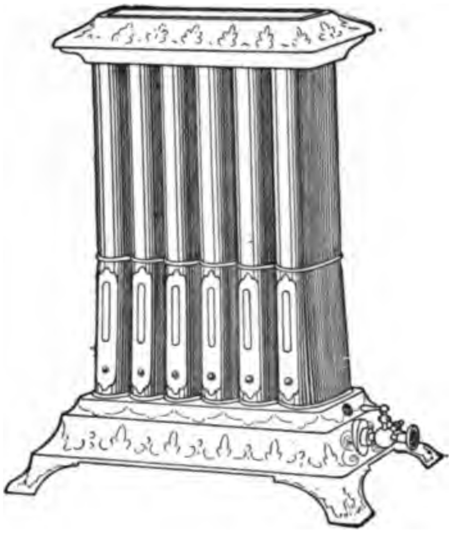


Fig. 129. Gas Radiator.

fire for heating is not so cheap as a coal fire when kept burning constantly. In other ways it is effective and convenient. It is especially adapted to the warming of small apartments and single rooms where heat is wanted only occasionally and for brief periods of time. In the case of bedrooms, bathrooms, or dressing-rooms, a gas fire is preferable to other modes of warming, and is fully as economical. It may be used on cold winter days as a supplementary source of heat in houses heated by stoves or by furnaces. Again, a gas fire may be used as a substitute for the regular heating apparatus in a house, in the spring or fall, when the fire in the furnace or boiler has not yet been started. It is often employed as the only means for heating smaller bedrooms, guest rooms, and bathrooms, and for temporary heating in summer hotels where fires are required

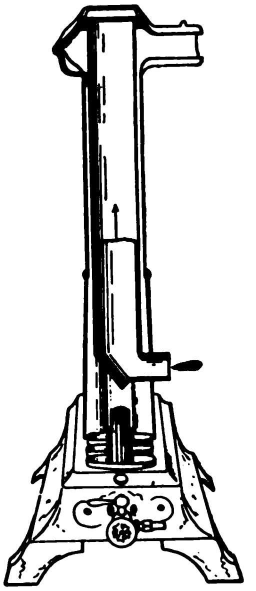


Fig. 130. Section of Gas Radiator of Fig. 129, Showing Flue to Connect to Chimney.

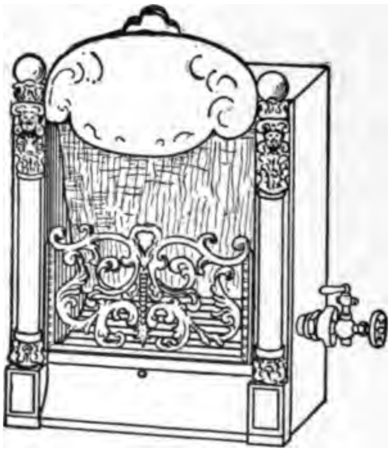


Fig. 131. Asbestos Incandescent Grate.

Fig. 132. Gas Log of Metal or Terra-Cotta and Asbestos.

only on occasional cold days. Any considerable use of gas for heating necessitates the use of evaporators to maintain the normal humidity of the air.

The most common form of heater is that shown in Fig. 128. This is easily carried from room to room, and may be connected with a gas-jet by means of rubber tubing, after removing the tip. The heater is merely a large burner surrounded by a sheet-iron jacket. Another and more powerful gas heater is the *radiator,* shown in Fig. 129. This is fitted with a flue to conduct the products of combustion into the chimney, as shown in the section, Fig. 130. Each section of the radiator consists of an outer and an inner tube, with the gas flame between the two. This space is connected with the flue, while the air to be heated is drawn up through the inner tube, as shown by the arrows.

Fig. 131 shows an *asbestos incandescent grate;* and Fig. 132, a *gas log* of metal or terra cotta and asbestos, made in imitation of a wood log or heap of logs. The gas issues through small openings in the logs, and gives the appearance of an open wood fire.

Fuel and Carburetted Air Gas. *Fuel gas* or *water gas,* largely made to supplement failing supplies of natural gas, is used for lighting in the same manner as natural gas. It is, in fact, but an impure commercial hydrogen made by injecting steam into hot coke. The oxygen of the steam combines with the carbon of the coke, and sets free the hydrogen, which is collected in a gasometer, ready for the distributing pipes. The prime use of this and of natural gases is for heating; but, by purifying it and supplementing it with carbon by incorporating with it vapors of petroleum, fuel gas makes rich and quite stable lighting gas.

Carburetted air, made by varnishing air with gasoline, generally called *gasoline gas,* is very different from any of the gases mentioned. Carburetted air gas of standard quality contains 15 per cent of gasoline vapor to 85 per cent of air. A regulator or mixer for supplying gas having these proportions is shown, in section, in Fig. 133. It consists of a cast-iron case, in which is suspended a sheet-metal can *B,* filled with air and closely sealed. The balance-beam *E,* to which this is hung, is supported by the pin *H,* on agate bearings. Since the weight of the can *B* is exactly balanced by the ball on the beam *E,* movement of *B* can be caused only by a difference in the weight or density of the gas inside the chamber *A* and surrounding the can *B*. If the gas becomes too dense, *B* rises and opens valve *C*, thus admitting more air; and if it becomes too light, *C* closes and partially or wholly shuts off the air, as may be required. This gas is not a stable mixture, and great care must be taken, in piping it, to avoid traps and give positive inclination to all the pipe. It is easily condensed by change of temperature; and fixtures through which it is used, must be of a pattern that drain to the keys, so that they can be removed with a screw-driver to drain the arms. The gravity of the mixture varies with the grade of gasoline used. It may always be taken as the weight of air *plus* the gasoline carried with the air. Hence the greatest pressure is always at the lowest instead of the highest point; and instead of lighting a burner by holding the flame over it, we apply the match below. In general, other rules for piping gas supply, with the exceptions mentioned, and these following: the pipe should always be a size larger than for coal gas, except that $\frac{3}{8}$-inch pipe may be run for two or three burners, and $\frac{3}{8}$-inch openings are permissible.

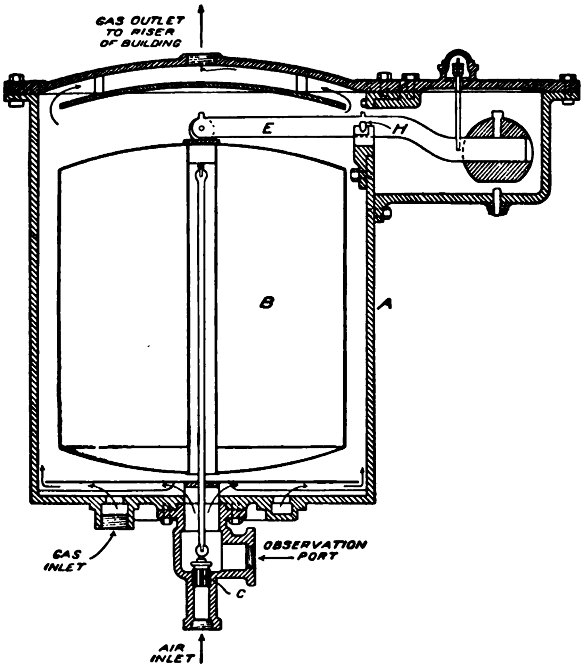


Fig. 133. Regulator or Mixer for Supplying Gas and Air Mixed in Certain Proportions.

To avoid having the pressure on the lower floor equal to the friction head of the whole system *plus* the weight of the gas, it is best to pipe the whole supply first to the top of the house. Then

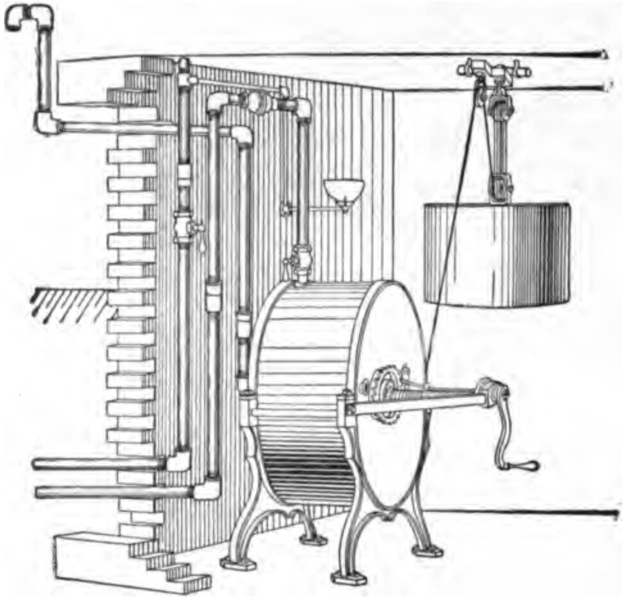


Fig. 134. Pump for Forcing Carburetted Air through House Pipes. Operated by Weight and Pulley. Pumps of this Kind are Sometimes Run by City Water-Pressure.

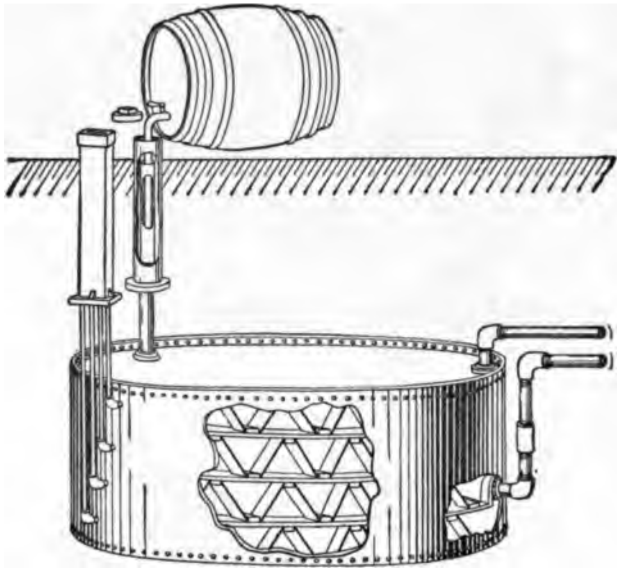


Fig. 135. Carburetter in which Air is Charged with Illuminant by Passing over a Certain Number of Square Inches of Gasoline Surface, Depending on the Number of Burners.

feed downward, and drip the main extremities into the initial main with a ⅜-inch connection. This permits circulation according to the temperature of the rooms; and, by giving just enough pressure at the pump to lift the gas easily to the top of the rising main, it feeds by gravity from that point. The least pressure possible is thus sufficient, and the pressure at each burner is constant.

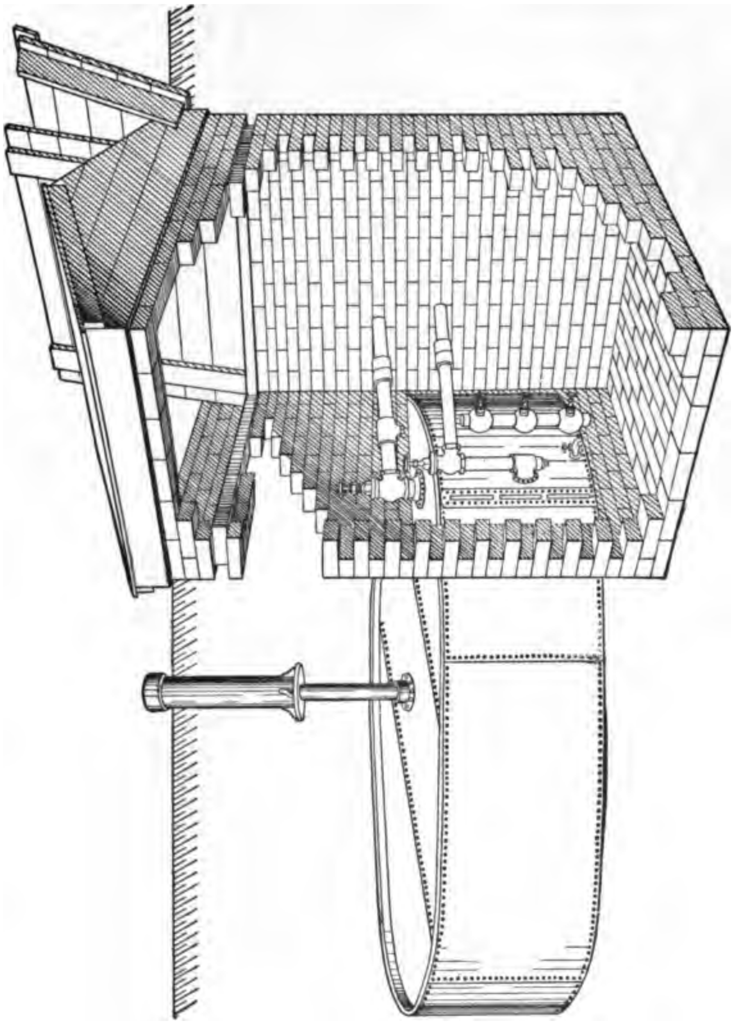


Fig. 136. Carburetter with Pit Giving Access to Transfer Cocks, Pump Pipes, etc.

With the exception of one or two machines, the use of Argand or other special burners is necessary. The *Clough burner,* oftenest used on gasoline, has an annular space below the tip, open at the top only. A thumb screw passes through the outer case, annular space, and inner wall, to the gas passage. When the carburetter is first filled, the gas is too rich, and the thumb-screws of the burners must be screwed out until the gas passing up can suck in more air from the annular space through the screw-hole. The gravity of the gasoline left in the carburetter grows constantly greater; carburization takes place correspondingly slower; and the gas delivered is accordingly poorer. This is because gasoline of various gravities is found in every barrel, and the air takes up the lightest first.

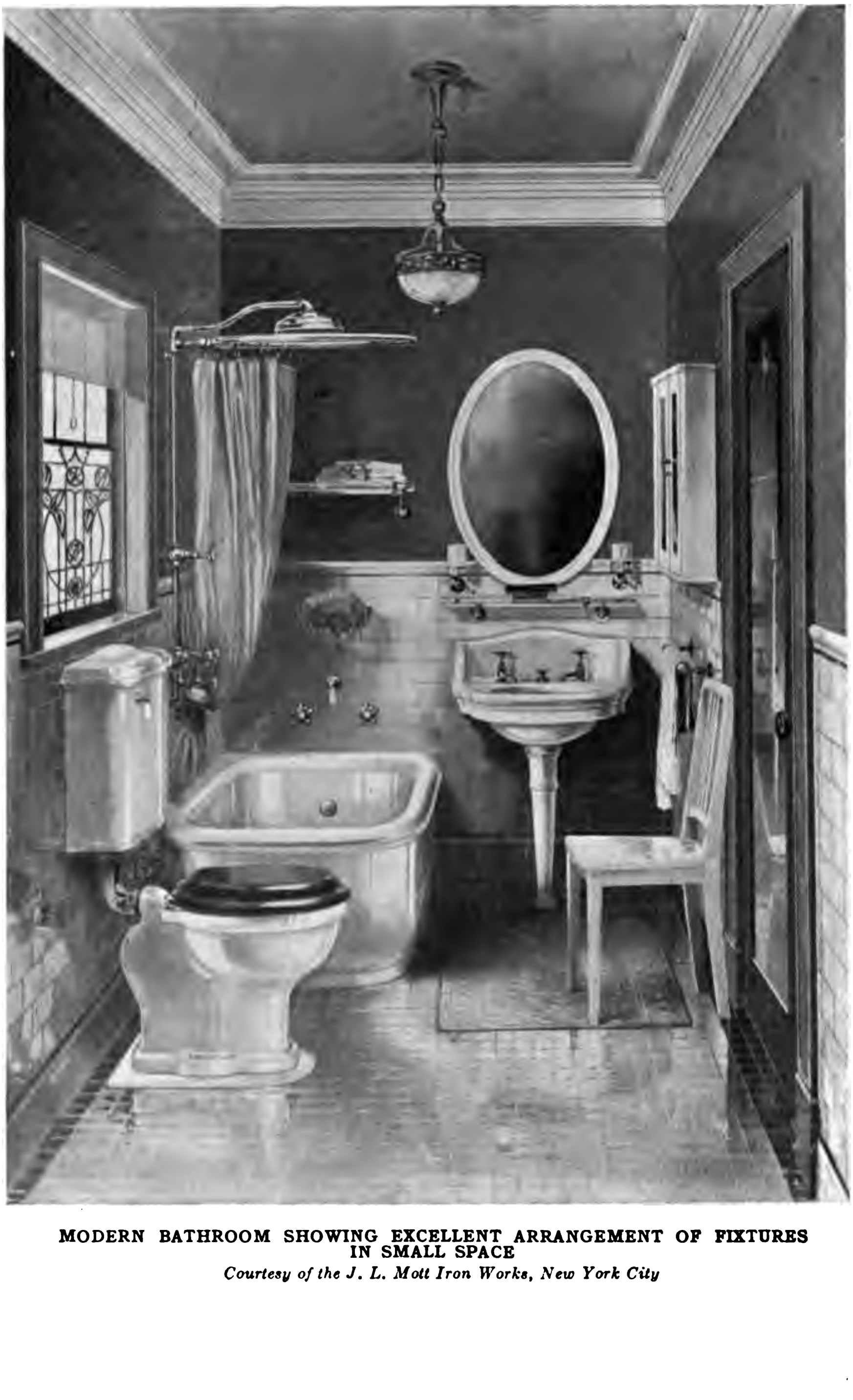
The pump for these machines is a sheet-metal case on legs, with an inner drum, made like the drum of a wet gas-meter and sealed with water. The drum is generally operated by a weight, through the medium of pulleys, and a cord is wound on a spool attached to a shaft extending from the drum through a stuffing-box, all about as shown in Fig. 134. The pump is placed in the basement, where it will not freeze. In some makes, city water-pressure is made to run the pump by means of a water-wheel, gravity and impingement of the stream both acting to revolve the drum.

Carburetters are made of sheet metal, galvanized iron, or copper. One form is simply a strong tank with a float and telescope pipe operating through a stuffing-box. The float is hollow, and the air is introduced to the carburetter through it. The weight of the float submerges the holes through which the air enters the carburetter; and, as flotation takes place on the gasoline itself, the air is thus charged with it and ready for the burner. This type of machine will come nearer carburetting all the gasoline of a charge than any other. Its fault is that the gas is too rich and smoky.

Another type of carburetter passes the air over a given number of square inches of gasoline surface per burner, as indicated by the construction shown in Fig. 135. Still another reduces the necessary superficial area of gasoline by looping burlap in the case in such a way as to compel the air to pass through the burlap, which is charged with gasoline by capillary attraction. Charcoal filling has been used for the same purpose.

The shape and dimensions of the simple carburetter have been changed for the better by introducing pans which overflow from one to another when filling. The required superficial surface is obtained in a much smaller case in this way. There is no method, however, of determining the necessary relative capacity of the pans; and transfer cocks, pump pipes, etc., have been resorted to—first, to replenish a pan if it becomes empty, and then to get the heavy residual product into one place where it can be pumped out. This form of machine requires a pit so that one can get down to the cocks and connections. A good form of pit construction is shown in Fig. 136.

Carburetters of nearly every make are placed in the ground, with or without pit, and are required by insurance companies to be at least 30 feet from any building. In some machines, mixers are employed to mix part of the air directly from the pump with the gas after it passes through the carburetter. The proportion of air thus mixed can be varied at will according to the quality of light desired. This feature is intended to make the use of ordinary coal-burners possible. The prices of machines constructed of the same material are a fair gauge of their relative merit.



MODERN BATHROOM SHOWING EXCELLENT ARRANGEMENT OF FIXTURES IN SMALL SPACE

Courtesy of the J. L. Mott Iron Works, New York City

PLUMBING

PART III

METHODS OF SEWAGE DISPOSAL

The fact that no specific gas peculiar to sewers and drains is known, and that the analysis of air taken from the interior of soil pipes has sometimes shown fewer germs capable of producing specific diseases than air taken from the room in which the pipes were situated, affords no reason for abating the effort to exclude drain, sewer, and soil-pipe air from buildings. In cities, the public sewers offer fixed conditions of sewage disposal; but where no public sewer is constructed, there are still a number of ways to handle the sewage from house sewers, and there are but few locations that do not offer at least one chance of settling the question in an unobjectionable manner.

For house disposal, *irrigation*, the *dry-and-wet well plan*, *streams*, and *dry ravines* are among the means most likely to be available. The *septic tank*, too, while its principles have as yet been employed only to a limited extent for individual houses, bids fair to come into extended use in the future.

The first cost of the *garden irrigation plan* is greater, usually, than that of other methods; but it has the merit of fertilizing the soil to some extent as a return for the expenditure. The solid matter must be carted away from time to time. The plan consists essentially of buried lines of irrigating pipe ramifying through the ground to be improved, and a specially formed receiver into which the house pipe leads and from which the irrigating lines are supplied, generally by intermittent siphonage. The solid matter subsides; and when a sufficient body has accumulated, the liquid is siphoned without personal attention. Fig. 137 shows the grease trap and siphon well of a garden irrigation plant. The chambers may be of concrete, or of brick laid in cement mortar and plastered. *KK* are iron cistern-covers with loose tops. The inlet pipe *E* from the house, has a hole in the crown of the bend, to prevent it from becoming air-bound when the well is full. *D* is the overflow to the siphon chamber, through which flows a quantity of sewage corresponding to that which at any time enters through the pipe *E*. *B* is a hood with notched bottom, placed over the central weir *A*. The contents of the siphon well rise through the hood, and pour over into *A* from all points, producing suction, which, with the aid of the tortuous outlet of *A*, causes periodical siphonage of the liquid down to a level below the teeth of the hood. *C* is a cone of wire mesh to protect *B* from becoming accidentally choked. *G* is an air-pipe with strainer at top; *H*, an air and overflow pipe combined; and *I*, the vitrified pipe main to the irrigating lines.

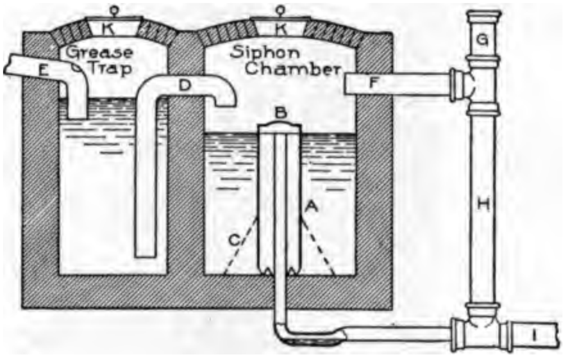


Fig. 137. Grease Trap and Siphon Well of a Garden Irrigation Plant.

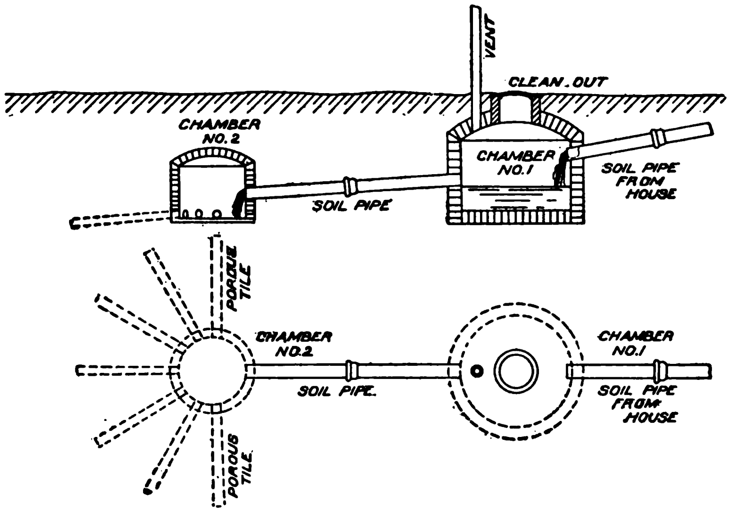


Fig. 138. Sectional Elevation and Plan of Cesspool for Septic Treatment of Sewage.

The irrigating lines are small, hubless, perforated tile arranged to accomplish, by means of tight headers properly inclined, as nearly as possible an even distribution of the liquid. This device—if properly constructed, and if placed at a suitable distance from the house, in such a position that it cannot contaminate a well or other source of water supply—can be used with comparative safety. Special care should be taken in its construction; and when in use, it should be regularly cleaned.

The slope of the ground necessary for the discharge of a siphon, generally meets the requirements of a better process—namely, the so-called *Septic*. The cesspool, shown in Fig. 138, is intended for this class of installation. It consists of two brick chambers, the larger having a clean-out opening in the top, provided with a tight cover. A vent pipe is carried from the top to such a height that all gases are discharged at an elevation sufficient to prevent nuisance from their presence. The smaller chamber is connected with the first by means of cast-iron soil-pipe, and is arranged to feed the lengths of porous tile radiating from the bottom, as shown in the plan view. The second chamber thus acts in lieu of the "tight headers" mentioned in connection with Fig. 137. The house drain connects with the larger chamber, which fills to the level of the overflow; then the liquid portion of the sewage drains over into chamber No. 2, and is absorbed through the porous tile branches. The solids, which are small in amount in a properly designed chamber, remain in No. 1, and may require removal from time to time. Unusual dilution and other favoring causes often produce more or less septic action in the second chamber. The intercepting trap may or may not be placed in the house drain.

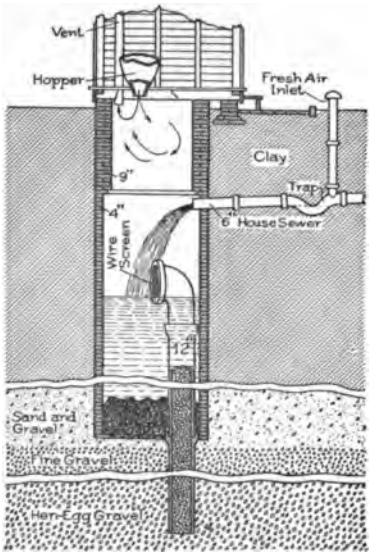


Fig. 139. Sectional Elevation of Dry-and-Wet Well.

Some natural, dry ravines are so formed and ence to the general surroundings as to offer little objection to their use as points of discharge for the house drain.

Streams should not be employed, unless they are of considerable size and have a constant flow, so as to accomplish sufficient dilution, unfailing throughout the season.

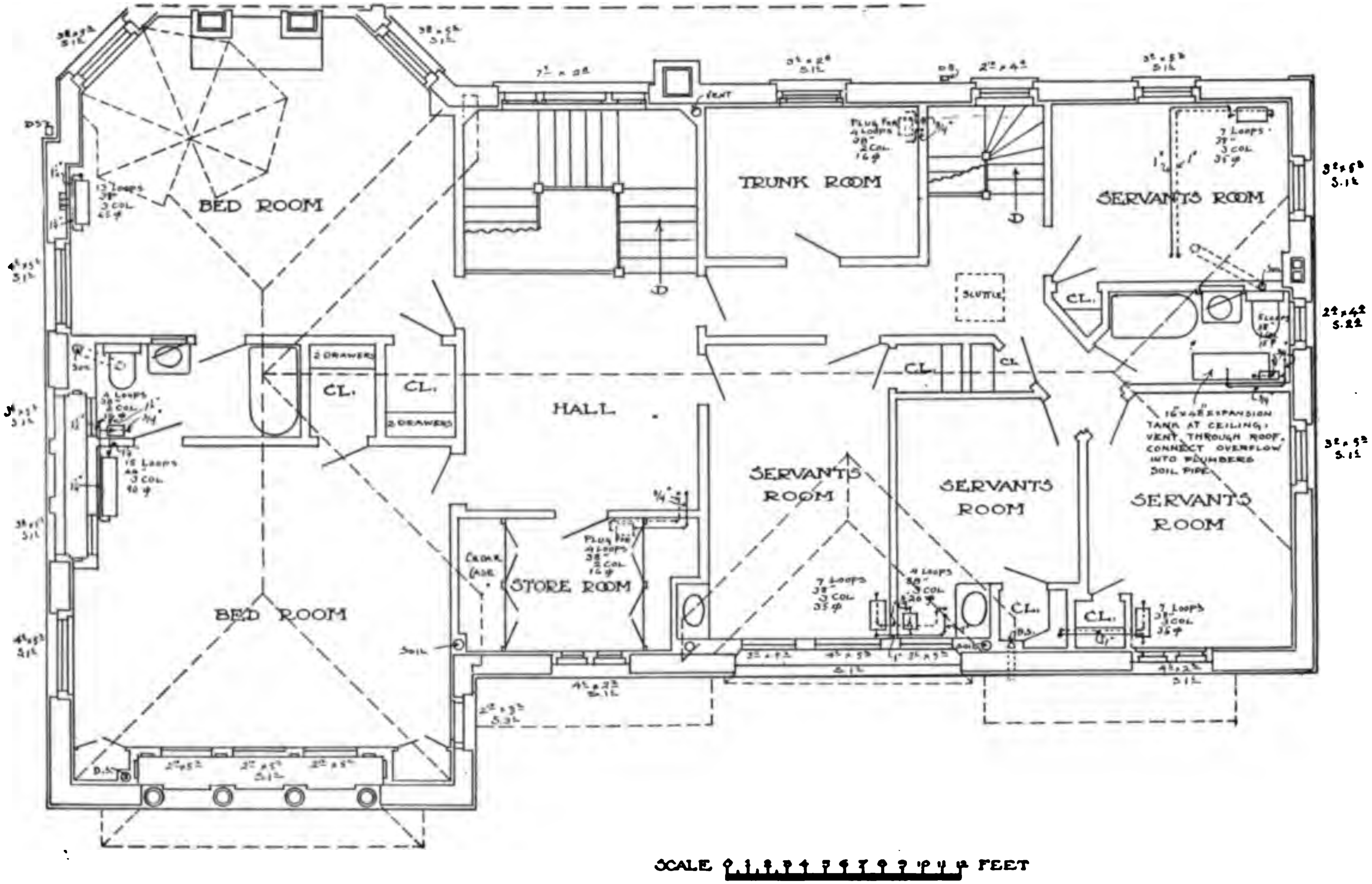
Near the urban limits, acreage available for disposal areas is small, and the land features and general environment so unfavorable that a *dry well* may sometimes be resorted to. This, in its best form—like the irrigation receiver—separates the solid from the liquid matter, and discharges the overflow of liquid, without much attention, into a stratum of ground in which certain bacterial processes take place. Fig. 139 is an elevation of a dry-and-wet well, which, when properly designed and installed, should operate through a long period without attention.

When the dry-well feature is added to an old vault, it is first necessary to connect the house sewer with the vault. The dry well consists of a 10 or 12-inch tile pipe extending to the gravel stratum and filled with broken rock. This pipe is made water-tight, both where it passes through the bottom of the vault, and within the vault as well. A heavy, grayish scum collects on the surface of the sewage, and indicates septic action. The liquid constantly flows over into the dry well, and some solid matter settles to the bottom.

The mention of this and other types of cesspools is not to be taken as a recommendation for their use, except when compulsory and after careful consideration given to their design. A sparsely settled condition of a locality reduces the harm possible from them; but under the most favorable conditions there is always danger of producing permanent pollution of the soil.

Marshes are sometimes unwisely used as a discharge place for the drain pipe. Isolated low spots covered with loosely piled broken rock to prevent the rooting of plants and to favor bacterial action, have given good service, evaporation and oxidation taking care of the discharge for long periods.

The septic treatment of sewage may be considered a biological rather than a chemical process, as its success is dependent upon presenting conditions which favor the rapid growth of certain bacteria. In the complete reduction of sewage by the septic method, bringing it to a harmless state in the form of nitrates which plant life can



THIRD-STORY PLAN OF RESIDENCE OF MRS. JAMES H. BARNARD, CHICAGO
W. Carbys Zimmerman, Architect, Chicago
For exteriors and other plans see pages 315, 330 and 346.

assimilate, two forms of bacteria are employed—*anaerobic* and *aerobic*. Air and light retard the multiplication of the first of these The second require oxygen, and multiply rapidly in the open air. The tank or receiver proper, is a sort of catch-basin, made in form to favor the requirements for the propagation of anaerobic bacteria, which reduce the sewage to simple compounds. The tank, it appears, should hold the output of about one day's use of the fixtures discharging into it. Light and air should be excluded. Warmth to a degree is essential. Such heat as is common to a pit in the earth, closed at the top, with no unnecessary exposure, together with the heat of waste water and that generated by the action taking place in the sewage itself, is sufficient to favor the process in winter weather of quite severe climates. A temperature of 54° F. has been stated to be the minimum permissible in this tank, for little or no septic action can take place at lower temperatures. The waste water of baths and lavatories is not turned into the septic tank merely for the heat it brings, but also to secure dilution of the excrement and matter from other sources, which not infrequently carry too little water to favor the best interests of the process. Both the inlet and the outlet of the tank should be arranged to be below the surface of the contents when the tank is full, so that the scum which generally forms on the surface will not be disturbed by entry or exit of matter. This scum, resembling wet ashes, helps to retain the heat, and excludes light and air from the mass—all favoring the accomplishment of the purpose. The scum may be from a few inches to 15 or 20 inches in thickness, according to conditions and nature of the plant.

The contents leaving this initial receptacle, having therein been reduced from a complex nature to one of simpler chemical compounds, principally nitrites, the completion of the reduction process and the change from nitrites to nitrates are brought about by exposure of the matter to light and air, giving the aerobic micro-organisms a chance to develop. This would be accomplished by simply discharging directly into a stream; but a more rapid action is obtained by interposing an open, shallow bed of broken stone or slag for the liquid to flow through first, so as to break up and bring into contact with the air as large an amount of surface as possible before piping to stream or elsewhere. In this way a more complete reduction is certain before the matter reaches any final source of disposal.

The bacteria necessary to the process are always present in abundance in fresh sewage, and nothing more than the time necessary to their cultivation is required in the simplest provision for operation. The resulting product is described as mainly consisting of a harmless, colorless, odorless, stable liquid. In this process, admission of air to the tank, or lack of sufficient heat or dilution, may result in a putrescent state of the matter, such as is occasionally found in a common cesspool.

As already noted, the septic process is not yet widely used, except for town sewage, where it is rapidly gaining in favor. Here elaborate methods are adopted to favor the aerobic or oxidizing end of the operation, mostly through filters of special design, all aiming to secure absolute stability and harmlessness of the final discharge from the sewage disposal plant.

Fig. 140 illustrates a simple arrangement for the septic treatment of sewage. *A* is the septic tank proper, where the anaerobic action takes place; and *B* is the second receptacle, with a bed of broken stone designed to break up the discharge from *A* in a way to favor aerobic action. *C* is the inlet, and *D* the outlet. Wider experience will doubtless develop much data bearing on the form of apparatus and the latitude of conditions under which particular grades of waste can be most successfully treated. Numberless variations from the arrangements shown are being employed, according to size of plant and composition of waste product. From ten to thirty days are required for the development of the bacteria and their action.

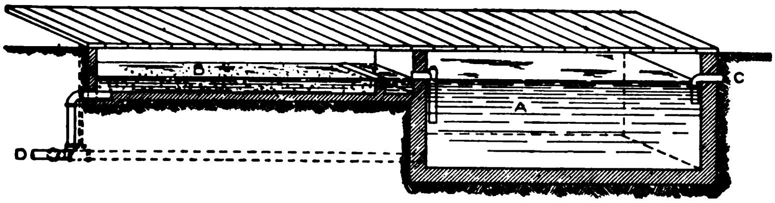


Fig. 140. Simple Tank Arrangement for Septic Treatment of Sewage.

Where the level of the outfall of a sewer for either an individual house or a community is below the level into which the final discharge must be made, it is necessary to use a sewage lift or pump to raise the matter to a point where gravitation will again take care of the flow. These lift pumps may be had suitable for either large or small installations. For sub-cellars or other points below the level of the main drain, surface drainage may be assembled in a well like that shown in Fig. 141; and from there, by means of a cellar drainer operated by steam or water, it may be automatically lifted and discharged into the drain, as shown by the engraving. The well is composed of metal rings about 30 inches in diameter, bolted together. One section is provided with pipe hubs for entry of the surface drain-pipes, and the cap is arranged with manhole opening and cover. If the drain into which the water is discharged is subject to reverse currents from tide or flood water, than a trap, with tide-water valve, arranged as shown between *B* and *C*, is used; otherwise, a simple trapped connection, as indicated by pipe *A*, leads the discharge water into the sewer, and the work shown from *B* to *C* is omitted.

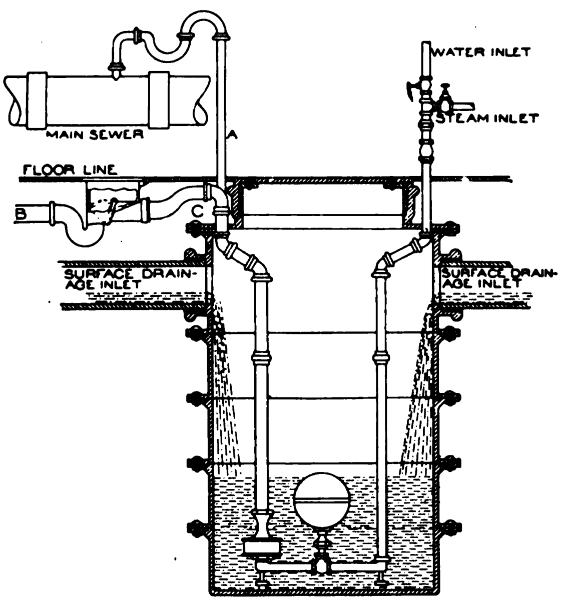


Fig. 141. Well for Collecting Surface Drainage from Sub-Cellars, etc., below Main Drain, into which it is Subsequently Lifted and Discharged.

A sanitary sewerage system cannot be installed until a public water supply has been provided. It is needed as soon as that is accomplished; for, while the wells may then be abandoned, the volume of waste water is greatly increased by the more copious water supply. Its foulness is also much increased through the introduction of water-closets. Without sewers and with a public water supply, cesspools must be used; and with these begins a continuous pollution of the soil much more serious than that which commonly results from vaults and the surface disposal of slops.

Among the data which should first be obtained in laying out a sewer system, are:

1. *The area to be served, with its topography and the general character of the soil.* A contour map of the whole town or city, showing the location of the various streets, streams, ponds, or lakes, and contour lines for each 5 feet or so of change in elevation, is necessary for the best results. The general character of the soil can usually be ascertained by observation and inquiry among residents or builders who have dug wells or cellars, or who have observed work of this kind being done. The kind of soil is important as affecting the cost of trenching, as well as its wetness or dryness; and this, together with a determination of the ground-water level, will be useful in showing the extent of under-draining necessary.

2. *Whether the separate or the combined system of sewerage, or a compromise between the two, is to be adopted.* These points will depend almost wholly upon local conditions. The size and cost of combined sewers is much greater than the separate system, since the surface drainage in times of heavy rainfall is many times as great as the flow of sanitary sewage. In older towns and cities, it sometimes happens that drains for removing the surface water are already provided; and in this case it is necessary only to put in the sanitary sewers; or again, the latter may be provided, leaving the matter of surface drainage for future consideration.

If the sewage must be purified, the combined system is out of the question, for the expense of treating the full flow in times of maximum rainfall would be enormous. Sometimes more or less limited areas of a town may require the combined system, while the separate system is best adapted for the remainder; and, again, it may be necessary to take only the roof water into the sewers. As already stated, local conditions and relative cost are the principal factors in deciding between the separate and combined systems.

3. *Whether subsoil drainage shall be provided.* In most cases this also will depend upon local conditions. It is always an advantage to lower the ground-water level in places where it is sufficiently high to make the ground wet at or near the surface during a large part of

the year. In addition to rendering the soil dry around and beneath cellars, the laying of underdrains is of such aid in sewer construction as to warrant their introduction for this purpose alone. This is the case where the trenches are so wet as to render the making and setting of cement joints difficult. The aim in all good sewer work is to reduce the infiltration of ground water into the pipes to the smallest amount; but in very wet soil, tight joints can be made only with difficulty, and never with absolute certainty. Cases have been known where fully one-half the total volume of sewage consisted of ground water which had worked in through the joints.

4. *The best means for the final disposal of the sewage.* Until recently it was the custom to turn sewage into the nearest river or lake where it could be discharged with the least expense. The principal point to be observed in the disposal of sewage is that no public water supply shall be endangered. At the present time, no definite knowledge is at hand regarding the exact length of time that disease germs from the human system will live in water. The Massachusetts Legislature at one time said that no sewer should discharge into a stream within 20 miles of any point where it is used for public water supply; but decisions on this point are now left largely in the hands of the State Board of Health. There may be cases where sewage disposal seems to claim preference to water supply in the use of a stream; but each case must be decided on its own merits. Knowing the amount of water, the prevailing conditions of flow, and the probable quantity and character of the sewage, it is generally easy to determine whether all of the crude sewage of a city can safely be discharged into the body of water in question. Averages in this case should never be used; the water available during a hot and dry summer, when the stream or lake is at its lowest and its banks and bed are exposed to the sun, is what must be considered.

Where sewage is discharged into large bodies of water—either lakes or the ocean—it is generally necessary to make a careful study of the prevailing currents, to determine the most available point of discharge, in order to prevent the sewage becoming stagnant in bays, or the washing ashore of the lighter portions. Such studies are commonly made with floats, which indicate the direction of the existing currents.

5. *Population, water consumption, and volume of sewage for*

which provision should be made, together with the rainfall data if surface drainage is to be installed. The basis for population studies is best taken from the Census reports, extending back many years. By means of these the probable growth can be estimated for a period of from thirty to fifty years. In small and rapidly growing towns, it must be remembered that the rate of increase is generally less as the population becomes greater.

It is desirable to design a sewerage system large enough to serve for a number of years, twenty or thirty perhaps, although some parts of the work, such as pumping or purification works, may be made smaller and increased in size as needed.

The pipe system should be large enough at the start to serve each street and district for a long period, as the advantages to be derived from the use of the city sewers are so great that all houses are almost certain to be connected with them sooner or later. It is often necessary to divide a city into districts, in making estimates of the probable growth in population. Thus the residential sections occupied by the wealthiest classes will consist of a comparatively small population per acre, due to the large size of the lots. The population will grow more dense in the sections occupied by the less wealthy, the well-to-do, and, finally, the tenement sections. In manufacturing districts the amount of sewage will vary somewhat, depending upon the lines of industry carried on.

The total water consumption depends mainly upon the population, but no fixed rule can be laid down for determining it beforehand. It is never safe to allow less than 60 gallons per day *per capita* as the average water consumption of a town, if most of the people patronize the public water supply. In general it is safer to allow 100 gallons.

The total daily flow of sewage is not evenly distributed through the 24 hours. The actual amount varies widely during different hours of the day. In most towns there should be little if any sewage, if the pipes are tight enough to prevent inward leakage, between about 10 o'clock in the evening and 4 o'clock in the morning. From two-thirds to three-fourths of the daily flow usually occurs in from 9 to 12 hours, varying in different communities. This is not of importance in designing the pipe system, but only affects the disposal.

Rainfall data are usually hard to obtain, except in cities and larger towns. In cases of this kind, the data from neighboring towns or cities may be used, if available. Monthly or weekly totals are of little value, as it is necessary to provide for the heaviest rains, as a severe shower of 15 minutes may cause more inconvenience and damage, if the sewers are not sufficiently large, than a steady rain extending over a day or two. A maximum rate of 1 inch per hour will usually cover all ordinary conditions. The proportion which will reach the sewers during a given time will depend upon local conditions, such as the slope of the land; whether its surface is covered with houses and paved streets, cultivated fields, or forests, etc.

6. *Extent and cost of the proposed system.* This is a matter largely dependent upon the local treasury, or the willingness of the people to pay general taxes or a special assessment for the benefits to be derived.

SEWER DESIGN AND CONSTRUCTION

The first step is to lay out the pipe or conduit system. For this, the topographical map already mentioned will be found useful. This, however, should be supplemented by a profile of all the streets in which sewers are to be laid, in order to determine the proper grades. In laying out the pipe lines, special diagrams and tables which have been prepared for this purpose may be used. In the separate system, it is generally best to use 12-inch pipe as the smallest size, to lessen the risk of stoppage, although 8 to 10-inch pipe is ample for the volume of sanitary sewage from an ordinary residence street of medium length. Pipe sewers are generally made of vitrified clay, with a salt-glazed surface. Cement pipe is also used in some cities. The size of pipe sewers is limited to 30 inches in diameter, owing to the difficulty and expense of making the larger pipe, and the comparative ease of laying brick sewers of any size from 24 or 30 inches up. In very wet ground, cast-iron pipe with lead joints is used, to prevent inward leakage or settling of the pipe.

The pipes should be laid to grade with great care, and a good alignment should be secured. Holes should be dug for the bells of the pipe, so that they will have solid bearings their entire length. If rock is encountered in trenching, it will be necessary to provide a bed for the pipe which will not be washed into fissures by the stream of subsoil water which is likely to follow the sewer when the ground is saturated.

Underdrains. Where sewers are in wet sand or gravel, underdrains may be laid beneath or alongside the sewer. These are usually made of ordinary agricultural tiles, 3 inches or upward in diameter. They have no joints, being simply hollow cylinders, and are laid with their ends a fraction of an inch apart, wrapped with cheap muslin cloth to keep out the dirt until the matter in the trench becomes thoroughly packed about them. These drains may empty into the nearest stream, provided it is not used for a public water supply.

Manholes. These should be placed at all changes of grade, and at all junctions between streets. They are built of brick, and afford access to the sewer for inspection; in addition to this, they are sometimes used for flushing. They are provided with iron covers, which in many cases are pierced with holes for ventilation.

Sewer Grades. The grades of sewers should, where possible, be sufficient to give them a self-cleaning velocity. Practical experiments show that sewers of the usual sections will remain clear with the following minimum grades: Separate house connections, 2 per cent (2-foot fall in each 100 feet of length); small street sewers, 1 per cent; main sewers, 0.7 per cent. These grades may be reduced slightly for sewers carrying only rain or quite pure water.

The following formula may be used for computing the minimum grade for a sewer of clear diameter equal to *d* inches, and either circular or oval in section:

$$\text{Minimum grade, per cent} = \frac{100}{5d + 50}.$$

Flushing Devices. Where very low grades are unavoidable, and at the head of branch sewers, where the volume of flow is small, flushing may be used with advantage. In some cases water is turned into the sewer through a manhole, from some pond or stream or from the public waterworks system. Generally, however, the water is allowed to accumulate before being discharged, by closing up the lower side of the manhole until the water partially fills it, and then suddenly releasing it and allowing the water to rush through the pipe. Instead of using clear water from outside for this purpose, it may be sufficient at some points on the system simply to back up the sewage, by closing the manhole outlet, thus flushing the sewer with the sewage itself.

Where frequent and regular flushing is required, automatic devices are often used. These usually operate by means of a self-discharging siphon, although there are other devices operated by means of the weight of a tank which fills and empties at regular intervals.

House Connections. Provision for house connections should be made when the sewers are laid, in order to avoid breaking up the streets after the sewers are in use. Y-branches should be put in at frequent intervals, say from 25 feet upwards, according to the character of the street. When the sewer main is deep down, quarter-bends are sometimes provided; and the house-connection pipe is carried vertically upwards to within a few feet of the surface, to avoid deep digging when connections are made.

Where house connections are made with the main, or where two sewers join, the direction of the flow should be kept as nearly the same as possible, and the entering sewer should be at a little higher level, in order to increase the velocity of the inflowing sewage.

Depth of Sewers below Surface. No general rule can be followed in this matter, except to place the sewers low enough to secure a proper grade for the house connections which are to be made with them. They must be kept below a point where there would be trouble from freezing; but the natural depth is sufficient to prevent this in most cases.

Ventilation of Sewers. There is more or less difference of opinion in regard to the proper method of ventilating sewer mains. Ventilation through soil-pipe foul-air outlets carried above the roof-level, with the aid of street manhole gratings, constitutes the usual procedure, though not entirely satisfactory. If air inlets and outlets were placed on the main sewers at intervals of 300 feet or so, the accumulation of air-pressures which now obtains would be prevented. The omission of all intercepting traps would result in the uniform ventilation of the public sewers through the various house pipes, and, in the opinion of some, is highly desirable.

The Combined System. The principal differences between the combined and the separate system lie in the greater size of conduits in the combined system, and the admission of surface water. Combined sewers are generally of brick, stone, or concrete, or a combination of these materials, instead of vitrified pipe. Another difference is the provision for *storm overflows*, by means of which the main sewers, when overcharged in times of heavy rainfall, can empty a part of their contents into a nearby stream. At such times the sewage is diluted by the rain-water, while the stream which receives the overflow is also swollen.

Size, Shape, and Material. The actual size of the sewer, and also to a large extent its shape and the material of which it is constructed, depend upon local conditions. Where the depth of flow varies greatly, it is desirable to give the sewer a cross-section to suit all flows as fully as possible.

The best form of section to meet these requirements is that of an egg with its smaller end placed downward. With this form the greatest depth and velocity of flow are secured for the smallest amount of sewage, thus reducing the tendency to deposits and stoppages. Where sewers have a flow more nearly constant and equal to their full capacity, the form may be changed more nearly to that of an ellipse.

For the larger sewers, brick is the most common material, both because of its low cost and the ease with which any form of conduit is constructed. Stone is sometimes used on steep grades, especially where there is much sand in suspension, which would tend to wear away brick walls. Concrete is used where leakage may be expected or where the material is liable to movement, but is more commonly used as a foundation for brick construction.

A *catch-basin* is generally placed at each street corner, and provided with a grated opening for giving the surface water access to a chamber or basin beneath the sidewalk, from which a pipe leads to the sewer. Catch-basins may be provided with water traps to prevent the sewer air from reaching the street; but traps are uncertain in their action, as they are likely to become unsealed through evaporation in dry weather. To prevent the carrying of sand and dirt into the sewers, catch-basins should be provided with silt chambers of considerable depth, with overflow pipes leading to the sewer. The heavy matter which falls to the bottom of these chambers may be removed by buckets and carted away at proper intervals.

Storm Overflows. The main point to be considered in the construction of storm overflows is to ensure a discharge into another conduit when the water reaches a certain elevation in the main sewer. This may be carried out in different ways, depending upon the available points for overflow.

Pumping Stations. The greater part of the sewerage systems in the United States operate wholly by gravity; but in some cases it is necessary to pump a part or the whole of the sewage of a city to a higher level. In general the sewage should be screened before it reaches the pumps.

Where pumping is necessary, receiving or storage chambers are sometimes used to equalize the work required of the pumps, thus making it possible to shut down the plant at night. Such reservoirs should be covered, unless in very isolated localities. The force main or discharge pipe from the pumps is usually short, and is generally of cast iron put together in a manner similar to that used for water-supply systems.

Tidal Chambers. Where sewage is discharged into tide water, it is often necessary to provide storage or tidal chambers, so that the sewage may be discharged only at ebb tides. These are constructed similar to other reservoirs, except that they must have ample discharge gates, so that they can be emptied in a short time. They are sometimes made to work automatically by the action of the tide.

SEWAGE PURIFICATION

Before taking up this subject in detail, it will be well to consider what sewage is, from a chemical standpoint.

When fresh, sewage appears at the mouth of an outlet sewer as a milky-looking liquid with some large particles of matter in suspension, such as orange peels, rags, paper, and various other articles not easily broken up. It often has a faint, musty odor, and in general appearance is similar to the suds-water from a family laundry. Nearly all of the sewage is water, the total amount of solid matter not being more than 2 parts in 1,000, of which half may be organic matter. It is this 1 part in 1,000 which should be removed, or so changed in character as to render it harmless.

The systems of purification now in most common use are the *septic treatment* already described, *chemical precipitation*, and the *land treatment*. *Mechanical straining*, *sedimentation*, and *chemical precipitation* are largely removal processes; while *land treatment*, by the slow process of infiltration or irrigation, changes the decaying organic matter into stable mineral compounds.

Sedimentation. This is effected by allowing the suspended matter to settle in tanks. The partially clarified liquid is then drawn off, leaving the solid matter, called *sludge,* at the bottom for later disposal. This system requires a good deal of time and large settling-tanks, and until recently has been considered suitable only for small quantities of sewage.

Mechanical Straining. This is accomplished in different ways, with varying degrees of success. Wire screens or filters of various materials may be employed. Straining of itself is of little value except as a step to further purification. Beds of coke from six to eight inches in depth are often used with good results.

Chemical Precipitation. Sedimentation alone removes only such suspended matter as will sink by its own weight during the comparatively short time which can be allowed for the process. By adding certain substances, chemical action is set up, which greatly increases the rapidity with which precipitation takes place. Some of the organic substances are brought together by the formation of new compounds; and, as they fall in flaky masses, they carry with them other suspended matter.

A great number and variety of chemicals have been employed for this purpose; but those which experience has shown to be most useful are lime, sulphate of alumina, and some of the salts of iron. The best chemical to use in any given case depends upon the character of the sewage, and on relative cost in the particular locality where it is to be used. Lime is cheap, but the large quantity required greatly increases the amount of sludge. Sulphate of alumina is more expensive, but it is often used to advantage in connection with lime. Where an acid sewage is to be treated, lime alone should be used.

The chemicals should be added to the sewage, and thoroughly mixed, before it reaches the settling-tank; this may be effected by the use of projections or baffling-plates placed in the conduits leading to the tank. The best results are obtained by means of long, narrow tanks; and they should be operated on the *continuous* rather than the *intermittent* plan. The width of the tank should be about one-fourth its length. In the continuous method, the sewage is constantly flowing into one part of the tank and discharging from another. In the intermittent system, a tank is filled and then the flow is turned into another, allowing the sewage in the first tank to come to rest. In the continuous plan, the sewage generally flows through a set of tanks without interruption until one of the compartments needs cleaning. The clear portion is drawn off from the top, the sludge is then removed, and the tank thoroughly disinfected before being put in use again.

The satisfactory disposal of the sludge is a somewhat difficult problem. The most common method is to press it into cakes, which greatly reduces its bulk and makes it more easily handled. These are sometimes burned, but are more often used for fertilizing purposes. In some cases, peat or some other absorbent is mixed with the sludge, and the whole mass removed in bulk. In other instances, the sludge is run out on the surface of coarse gravel beds, and reduced by draining and drying. In wet weather, little drying takes place; and during the cold months, the sludge accumulates in considerable quantities. This process also requires much manual labor, and in many cases suitable land is not available for the purpose. The required capacity of the settling-tanks is the principal item in determining the cost of installing precipitation works.

In the treatment of house sewage, provision must be made for about $\frac{1}{12}$ the total daily flow; and in addition to this, allowance must be made for throwing out a portion of the tanks for cleaning and repairs. In general, the tank capacity should not be much less than $\frac{1}{8}$ the total daily flow.

In the combined system, it is impossible to provide tanks for the total amount; and the excess due to storm water must discharge into natural watercourses or pass by the works without treatment.

Broad Irrigation or Sewage Farming. Where sewage is applied to the surface of the ground upon which crops are raised, the process is called *sewage farming*. This varies but little from ordinary irrigation, where clean water is used instead of sewage. The land employed for this purpose should have a rather light and porous soil, and the crops should be such as require a large amount of moisture. The application of from 5,000 to 10,000 gallons of sewage per day per acre is considered a liberal allowance. On the basis of 100 gallons of sewage per head of population, this would mean that one acre would care for a population of from 50 to 100 people.

Sub-Surface Irrigation. This system is employed, as already described, only upon a small scale, and chiefly for private dwellings, public institutions, and small communities where for any reason surface disposal would be objectionable. The sewage is distributed through agricultural drain tiles laid with open joints and placed only a few inches below the surface. Provision should be made for changing the disposal area as often as the soil may require, by turning the sewage into other subdivisions of the distributing pipes.

Intermittent Filtration. This method, and the broad irrigation already described, are the principal purification processes—not considering the septic method—in use on a large scale, which can remove practically all the organic matter from sewage without being supplemented by some other method. The process is a simple one, and consists in running the sewage out through distributing pipes on beds of sand 4 or 5 feet in thickness, with a system of pipes or drains below for collecting the purified liquid. In operation, the sewage is turned first on one bed and then on another, thus allowing an opportunity for the liquid portion to filter through. As the surface becomes clogged, it is raked over, or the sludge may be scraped off together with a thin layer of sand. The best filtering material consists.of a clean, sharp sand with grains of uniform size, such that the free space between them will equal about one-third the total volume. When the sewage is admitted to the sand, only a part of the air is driven out, so that there is a store of oxygen left, upon which the bacteria may draw. This is not a mere process of straining, but the formation of new compounds by the action of the oxygen in the air, thus changing the organic matter into inorganic. Much depends upon the size and quality of the sand used.

The work done by a filter is largely determined by the finer particles of sand, and that used should be of fairly uniform quality, and the coarser and finer particles should be well sized. The area and volume of sand or gravel required are so large that the transportation of material any great distance is out of the question. Usually the beds are constructed on natural deposits, the top soil or loam being removed. The sewage should be brought into the beds so as to disturb their surface as little as possible, and should be distributed evenly over the whole bed.

The underdrains should not be placed more than 50 feet apart, usually much less, and should be provided with manholes at the junctions of the pipes. Before admitting the sewage to the beds, it is usually best to screen it sufficiently to take out paper, rags, and other floating matter. The size and slope of each bed should be such as to permit an even distribution of sewage over its surface.

Where the filtration area is small, it must be divided so as to permit of intermittent operation; that is, if a bed is to be in use and at rest for equal periods, then two or more beds will be necessary, the number depending on the relative periods of use and rest. Some additional area should also be provided for emergency, or for use while the beds are being scraped. If a large area is laid out, so that the size of the beds is limited only by convenience in use, then an acre may be taken as a good size.

The degree of purification depends upon various circumstances; but with the best material, practically all of the organic matter can be removed from sewage by intermittent filtration, at a rate of about 100,000 gallons per day.

There is often much opposition to sewage purification by those living or owning property near the plants; but experience has shown that well-conducted plants are inoffensive, both within and without their enclosures. The employees about such works are as healthy as similar classes of men in other occupations. The crops raised on sewage farms are as healthful as those of the same kind raised elsewhere; and meat and milk from sewage farms are usually as good as when produced under other conditions. Good design and construction, followed by proper methods of operation, are all that are needed to make sewage purification a success. No one system can be said to be the best for all localities. The special problems of each case must be met and solved by a selection from among the several systems and combinations of systems, and parts chosen that are best adapted to the conditions at hand.

Where sewerage and storm water are carried in one system of pipes or conduits, rain-water leaders may ventilate the drain more or less. Trapping a leader drain is often unnecessary, if it opens above the highest windows. Porch and veranda roof drains having windows above them may require trapping, but it should be done in a way to insure the maintenance of the water-seal of the trap. As these drains are small, merely connecting to the main drain inside (on the house side), the main intercepting trap may be deemed sufficient unless closure by hoar frost is likely. Other pipes so connected being higher, the chances are that air will enter the open end to supply a current up the taller lines; and if this is not the case, dilution of what air may be thus brought into the open will render its danger of little consequence. Care must be taken in the design of a system of plumbing, that leader traps are not omitted where such omission would result in the weakening of the flow of air through the principal vent pipes.

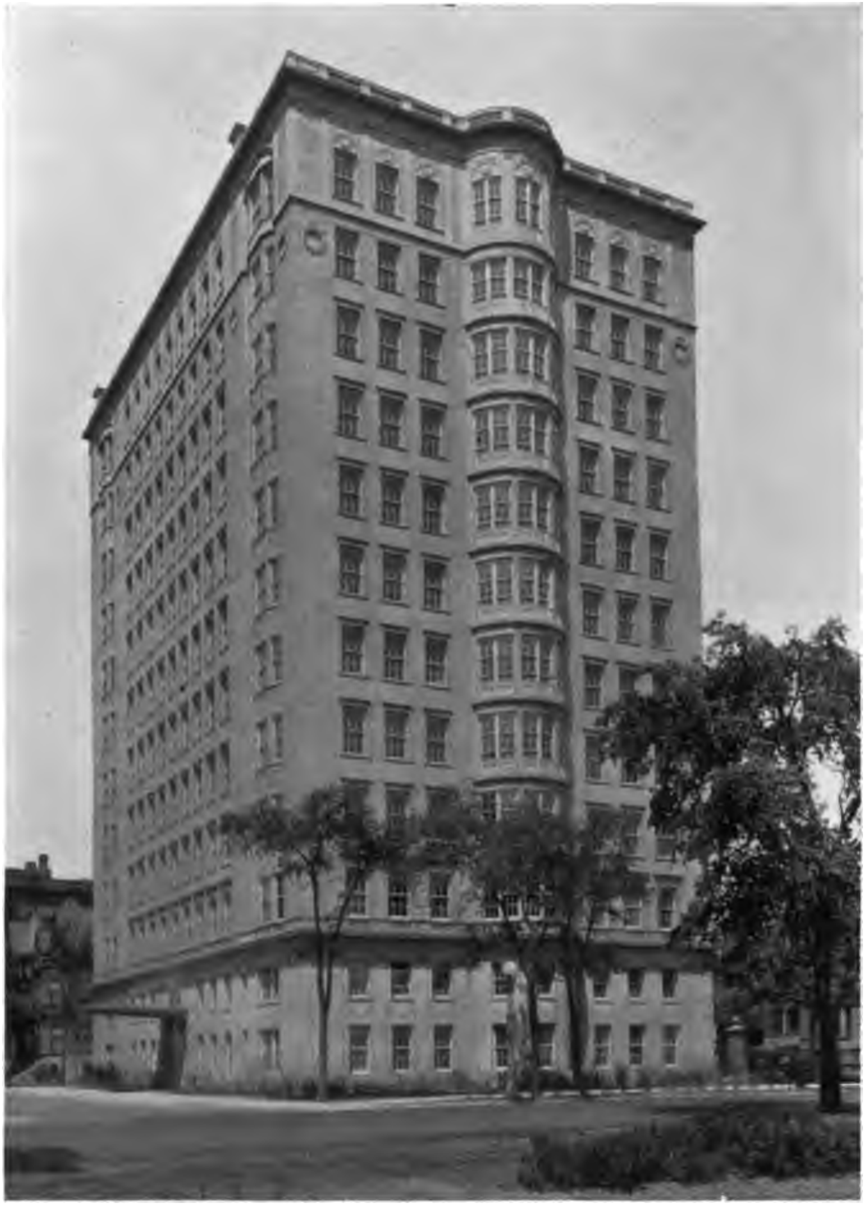
THE HOUSE DRAINAGE SYSTEM

Assuming that the method of disposing of sewage and drainage is decided upon, the problem of how to pipe the house safely may be considered as presenting about the same conditions, whether the house drain enters a branch from the city sewer or terminates in some other means of disposal.

Granted that sewer air is a thing to be guarded against, the safest plan is to pursue that course which offers the surest means of keeping the house free of it. We know that through contamination of water supply by filtration from vaults, etc., the human system may suffer pollution, and may develop specific disease of a serious, even fatal nature. It is no less certain that polluted air will affect the lungs similarly, according to the nature of the pollution. On this ground, notwithstanding any argument to the contrary, we should proceed to exclude sewer air entirely, and to make the air of the house drain-pipes as pure as possible.

It must be remembered that where a whole system of plumbing is designed with certain ends in view, and all the details worked out accordingly, a house system may be satisfactory which under slight disturbance of conditions would be abominable. Therefore no departure from a certain means of positively accomplishing a desired result should be accepted without unanimous endorsement of those in position to know what is safe. People, however, have been at all times too ready to accept any plan that promised the immediate saving of a dollar. Certain plumbing accessories may be admirably adapted to use in one place, yet wholly unfit for service in another; but the makers cannot be expected to discriminate; they are prejudiced, and are not on the ground. It is the business of the public, through architects and plumbers, to select suitable means to the end.

With the fresh-air inlet and proper installation throughout the building, an intercepting trap is likely to exclude sewer air from the



STEWART APARTMENTS ON LAKE SHORE DRIVE, CHICAGO
Marshall and Fox, Architects, Chicago

house, and to keep the drains in the house filled with fresh air from the open atmosphere (see page 163). With these conditions, a possible leaky joint or defective trap can permit only comparatively pure air to enter from the pipe. The intercepting trap being in the main line, all water from the house passes through it, insuring the water seal being maintained. The foul-air outlet ventilates the sewer much as would the house lines if the trap were omitted, because in it there is never any contrary rush of air or water, both of which would check or reverse the current, and the latter of which reduces the area of the pipe, even though it be assumed that no further interference occurs through discharge from fixtures. The trap may be in the yard or within the house walls, according to circumstances.

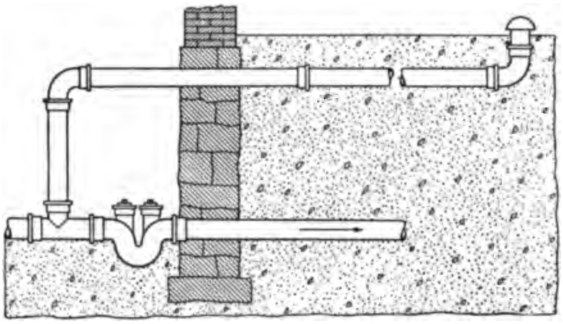


Fig. 142. Intercepting Trap in Cellar.

Fig. 142 shows an intercepting trap in the cellar, with its fresh-air inlet terminating above the snow-level. Many jobs were formerly piped in a way permitting soil air to puff out through the inlet. Fig. 143 shows a plan that has been resorted to with the idea of carrying such discharges to a safe height without interfering with the normal action of the fresh-air inlet. It is merely a rising line with an inverted funnel over the open end of the inlet, which incidentally protects the air-pipe from lodgment of foreign matter. The foul-air outlet should not terminate near a window or

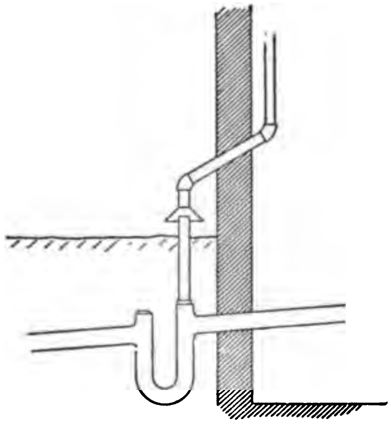


Fig. 143. Simple Device for Carrying Away to a Safe Height Soil Air that may be Puffed from Fresh-Air Inlet.

door, nor be too close to the fresh-air inlet opening. It should be located so that it will be free of chance obstruction, and above the level of winter ice and snow, even though it has to be piped to above the roof-level as indicated in Fig. 144, in which *A* is a cone strainer with solid top, and *T* the main intercepting trap. The direct line of foul-air pipe to roof, and the distance between the trap and fresh-air inlet grating, provide every requisite possible to this part of the house drainage, whether a *loop stack,* spoken of on another page, is employed or not.

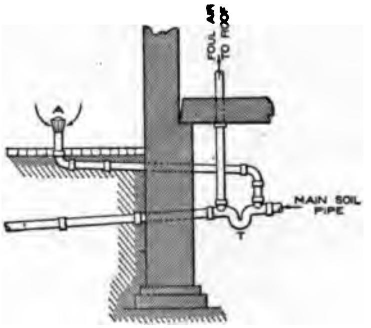


Fig. 144. Foul-Air Outlet from Intercepting Trap Carried to Roof.

A very good plan of terminating air inlet and outlet pipes in situations exposed to the entrance of obstacles, is to use a single or double hub return bend above snow-level, as shown in Fig. 145. In this way, nothing can fall in by accident; sleet from any direction cannot choke the openings; nor are children likely to fill the pipe.

Fig. 146 illustrates a galvanized-wire guard placed in the hub; such a guard is generally used on conductor pipe, but is equally suited to the protection of soil and vent lines in mild climates. In Northern localities, the regular cast hood and thimble made for the purpose are better. The area of the openings of the strainer should aggregate at least 12 square inches for pipe 4-inch or less; and where frost trouble is feared, the strainer should be recessed several inches so that the frost will have to close the open end of the pipe instead of the grating.

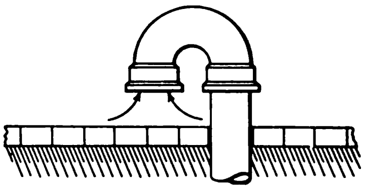


Fig. 145. Return Bend Used to Terminate Air Inlet or Outlet Pipe.

The foul-air pipe should not have abrupt offsets at any point. The lodgment of foreign matter therein would be possible, and the function of the pipe perhaps thus impaired. This pipe not only ventilates the sewer, but offers egress for air when storm water is crowding the sewer, and at other times when air-pressure would otherwise drive the seal of the trap toward the house, enough ultimately, in some cases, to lose the seal by waving out when the pressure is relieved.

When a trap loses its seal by waving out, the water, in flowing back to its normal position, gains momentum enough to throw some of it over the weir, and the balance is not enough to seal the trap. Waving out is always caused, first, by air-pressure on the sewer side, and then by gravity acting as described.

The operation of the fresh-air inlet depends on air from the open entering the house drain near the trap and filling the house system, passing out through the vent pipe above the roof. The inlet should be as large as the house sewer, which should never be less than 4 inches diameter, usually 5 inches. The same precautions taken against snow and ice and other obstructions to the foul-air outlet, are necessary to the fresh-air inlet. The difference in level of the inlet and the exit, together with the warmth of the building, causes an upward current through the stack. Even the taking a more exposed course and stopping at an elevation inferior to the outlet of the soil-pipe extension, when necessary to carry the inlet to the roof, will usually insure a draft.

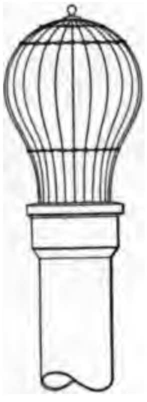


Fig. 146. Galvanized-Wire Guard at End of Pipe.

Objection is often raised against the fresh-air inlet, for the reason that puffs of foul air are thrown out when fixtures are discharged. This is easily possible, but mainly the result of faulty installation. One feature of plumbing is no more likely to be satisfactory than another where ignorance prevails, or when merely the simple letter instead of the spirit of ordinary specifications is lived up to. House main lines of the same size as soil-stacks (4-inch) will cause puffs of air from the fresh-air inlet if the horizontal run and the inlet branch are both short. It is well to remember that the air so puffed out is not sewer air. It is air which has just entered the house system from the open. And, if the fresh-air branch is of decent length, as described, and as shown in Fig. 144, the puff occasioned by the discharge of a fixture in an ordinary house, even in an objectionable job, may not equal a third of the really fresh air in the inlet branch.

The chance of puffing under the action of fixtures can be avoided by a loop providing for simple revolution of air when fixtures are discharged. A soil-stack from the main horizontal line is carried up to the roof, with all connections as usual, except one. This is made above the highest fixture, and of the same size as the soil-stack, and is generally carried down and connected, as it should be, into the horizontal main several feet nearer the intercepting trap than where the corresponding soil-stack leaves the main. Some connections are so close to the point of exit that the vertical stacks are made to constitute the whole loop, as shown in Fig. 147, in which cases the direct stack *E* from *X* to *Y* should invariably be a portion of the vent. If the connection *X* is made in the horizontal run, as before mentioned, stack *F* should be the vent, as a rule, instead of carrying the closet branches *GG* as shown. *V* and *V* are crown vents for the closets. The crown vents may in some situations be made into a separate smaller line leading into the soil-stack above the highest fixture.

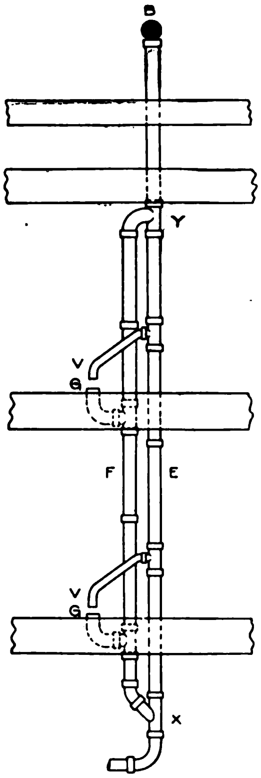


Fig. 147. Loops in Soil-Stack to Prevent Puffs of Air at Fresh-Air Inlet.

By the *loop* plan, air is thrust before the water discharged from a fixture as usual; also, there is the same tendency to a vacuum behind the water so discharged. But, instead of reversing the general current and drawing air from the roof to fill the void, the roof current in the soil-stack from the loop connection up, is merely checked, more or less; and the air already rising in the loop turns down the soil-stack and fills the void. Without the loop, considerable compression would take place in front of the water before the current in the house main could be reversed. With the loop, this compression is confined principally to the stack. The void being supplied by the loop, the air driven in front of the water simply passes up the loop in response to the call for air to fill the void behind the water.

Referring again to Fig. 147, air takes the course offering the least friction; and *F* branching out of and into *E*, which is the same size pipe as shown at *X* and *Y*, the greater part of a current of air passing upward through them will travel by pipe *E*. For this and other reasons it is best to take the branch pipe *F* for the soil pipe. Then, whatever offset may be necessary to reach the closet openings will be washed; and the straight, vertical stack left for the vent affords no chance for the lodgment of rust or other obstruction. When water is discharged into the soil pipe at *G*, pipe *V* protects the closet trap from siphonage; and the tendency to form a vacuum above the water in the soil pipe by the piston action of the discharge water, is neutralized by a proportional draught of air from vent pipe *E* through branch *Y*. The air in the vent pipe between *Y* and *B* tends to continue its course to the roof, while that below the branch *Y* is traveling toward branch Y. A partial vacuum formed in soil pipe *F* by a discharge from a fixture, will be checked by a supply of air drawn from vent pipe *E* between branches *X* and *Y*. The vacuum formed behind the discharge water in soil pipe *F* increases the upward velocity of air in vent pipe *E* below *Y*; and the air pushed down in front of the discharge attempts to reverse the current below *X*. The increased velocity of the air in pipe *E* demands more air than was passing through it by natural draught. This demand is supplied by the extra volume which the water is pushing before it.

As long as the discharge water is above branch *X*, the air simply revolves in the two pipes which form the loop. The air in pipe *F* travels downward before the water, and up through pipe *E* and branch *Y*, and down pipe *F* behind the water. This revolution of air in the loop continues until the water reaches the junction *X* of pipes *E* and *F*, without causing any perceptible "puff" at the fresh-air inlet opening.

When both the connections are in vertical lines as in Fig. 147, after the water passes *X*, it will probably reverse the current of air in the fresh-air pipe in some instances; but, were it possible to shove out every atom of air in the soil pipe between the trap and point *X*, there still would not be a particle of foul air puffed out at the fresh-air opening, if the fresh-air pipe is of greater length than the distance between *X* and the trap.

After the fixture water reaches *X* connection when *X* is made in a larger and horizontal pipe, its interference with the air is not considerable. The object in not connecting the loop stacks as close together as fittings will permit when they lead into a horizontal line, is to keep the water, as it turns into the horizontal main, from interfering with the entry of air to the vent. By giving some distance to travel before reaching the loop connection, the discharge of water will be well spread in the main line before passing it. From this point on, it may cause violent eddying of the air in the main, but no actual reversal of the current will take place.

The force of air in front of water in down spouts that connect inside of the intercepting trap, may at times reverse the air in the fresh-air inlet proper. The loop pipe is an aid in this respect, too, as more air is at hand to cushion the rush of a sudden downpour; and the various fixture trap seals are, if affected at all, left much more stable. It would, if necessary, be better to have soil-pipe air expelled from an inlet, at times, by the action of storm water, than to incur the risk of siphonage or waving-out of fixture trap seals for lack of it.

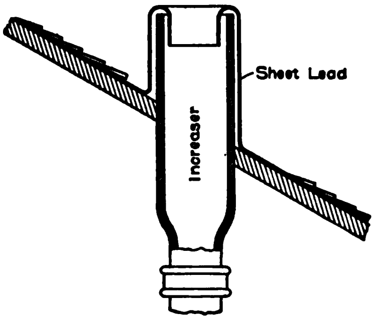


Fig. 148. Vent Pipe Increased in Size Before Passing through Roof, to Prevent Closure by Hoar Frost.

No pipe of any building should open to the air with less than a 4-inch end. Small pipes should be increased to 4 inches before passing through the roof, as shown in Fig. 148. Pipe 4-inch and larger, up to 6-inch, should be increased to 6-inch. The object in all cases being to prevent closure by hoar frost. With 6-inch and larger pipe, it is doubtful if it is ever necessary to increase the size at the roof, excepting in buildings with cold roof space, no matter how high the building may be; yet some city ordinances call for an increase of one size regardless of size, which is manifestly foolish, as it permits increasing 2-inch to 2½ or 3-inch on any type of job, and this is known to be inadequate in any but southerly latitudes. The velocity of air up the line is, of course, higher in tall buildings than in low ones; hence, in them, more moisture is carried through any given opening, and the theory of increasing large pipe at the exit is based on the assumption that smaller openings would, as a result of this excess of moisture, be closed by frost. The great amount of warmth over large buildings must often, however, be considered as reducing the chances of closure by hoar frost. In tropical climates, no increase of any size is necessary. In southerly temperate latitudes, no special attention is given precautions against hoar frost, beyond increasing the size of small vents to at least 4 inches in diameter.

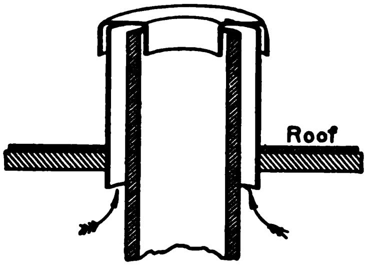


Fig. 149. Pipe Flashing Capped with V-Ring of Lead and Providing Egress for Warm Air from Attic.

Flashings. There are patent devices for flashing around pipes, usually made of copper; but the plumber will do well to command the skill necessary to manipulate sheet lead to suit conditions as he finds them. In any location where warm air will always be seeking an outlet from the attic through chance openings, the sleeve of the flashing may be made two to four inches larger than the outside diameter of the vent, and capped with an annular V-ring of lead in the manner shown in Fig. 149. The cap ring need only be tacked to the sleeve with solder. The top edge of the sleeve should be notched or some other provision for air-exit made, so as to insure constant changing of the air in the sleeve. If, on account of braces or projections necessary to hold the pipe rigid where it passes through the sheeting, it is inconvenient to let the sleeve extend below the sheeting as shown in the engraving, it may terminate at the roof line. If the building is a storage warehouse, or for any reason the attic will not be very warm, or conditions are in favor of cold air being drawn in through chance openings in winter, then the method of flashing and packing the sleeve with felt or mineral wool as shown in Fig. 150 should be employed. In all cases the vent and flashing must rise above the possible snow-level for flat roofs. The snow-level on a steep roof will be less, but drifts may obstruct the vent if left at the snow-level. Some latitude for

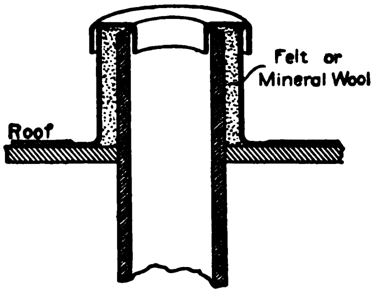
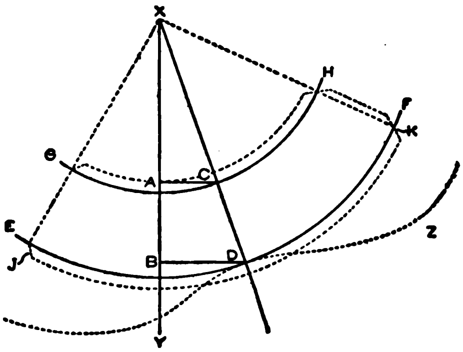


Fig. 150. Pipe Flashing Packed with Felt or Mineral Wool where it is Desirable to Conserve Warmth in Attic.

settling of the roof under the weight of snow and ice, and for expansion of lines supported by brick piers or other supports far below the roof-level must be allowed in fitting flashings. If they are too closely drawn or capped, trouble will soon follow.

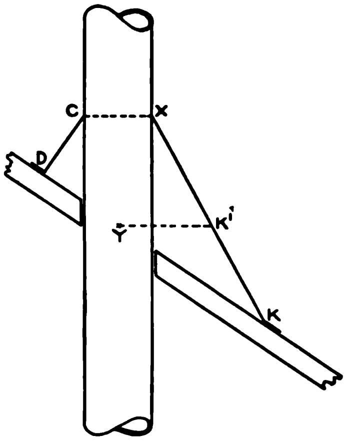
To develop the pattern for a tapering sleeve for a vent for a flat or nearly flat roof, draw, as in Fig. 151, XY at random; set off AB equal to the altitude of the sleeve; then AC from A, perpendicular to AB; then BD from B, parallel to AC; let AC equal half the diameter of the sleeve at the top, and BD half the bottom diameter; then cut CD with a line crossing XY. Lines AC, CD, DB, and BA now outline half the elevation of the sleeve at the center. Next, with the intersection of XY and CD projected (X in the diagram) as a center, describe the arcs EF and GH. On EF, set off the circumference of the base of the sleeve JK (twice $BD \times 3.1416$ equal circumference, which is equal to 6 radii or 6 times BD stepped on arc EF with the dividers), and then indicate JX and KX. This develops the net pattern, and it remains only to add the necessary working edges to get, when cut out and formed up, a sleeve of the exact shape and dimensions required.



No. 151. Development of Pattern for Tapering Sleeve for Vent on a Flat Roof

The development of a tapering sleeve for a pitched roof by strictly geometrical methods, is so intricate, and the springs and pitches of roofs so varied, that the plumber usually ignores—and is generally sensible in doing so—the true methods of cutting out such flashings. Lead is pliable, and flashings for pitched roofs can be roughly laid off as follows, and then worked and trimmed to suit.

The circumference and curvature of the top edge and lines of the ends can be joined, are obtained by full-size diagrams in the same way as for a sleeve for a flat roof, shown by Fig. 151. The circumference of the top edge is, in this case, set off on GH, because the bottom, corresponding to JK, is unknown. The elevation $ABCD$ is made just as though a sleeve was to be made for a flat roof, with the tapering side equaling *CD*, Fig. 152, which should be laid out to represent the elevation of the sleeve desired. The pattern diagram (Fig. 151) should be so drawn as to throw line *XCD* about the center or neck of the pattern, so as to bring the seam on the low side and thus present solid metal to the flow of water down the roof. The line of dots marked *Z* in Fig. 151, approximately outlines the bottom of the pattern, though the actual curves would be more or less pronounced, according to the pitch of the roof. The cross-mark guides by which to draw the bottom of the flashing, are seldom more than five in practice, and their positions are determined in this way: *JX* and *KX* of the pattern diagram are extended and set off from the *GH* line, Fig. 151, equal to *XK*, Fig. 152. This gives the actual seam length for the low side of the flashings, as would be indicated if *XJ* and *XK*, Fig. 151, were actually extended to cut the extremes of the guide line *Z*. *CD* of both the elevation and pattern diagram being equal, *CD*, Fig. 151, equals the length of sleeve in the neck or upper side. For the length of sleeve at the sides, half way between the neck and seam, produce dotted line $K^1 Y$, Fig. 152, parallel to *CX*, to a point where it will intersect the roof-plane at the center of the pipe space. K^1X will then be equal to the required side lengths of sleeve, and may be set off on the pattern diagram by projecting radii from *X*, cutting the pattern midway between *C* and the seam lines, and setting off the distance XK^1 on these radii, measuring from the *GH* line. These points are sufficient for approximating the bottom contour generally. When formed up, the bottom edge can easily be snipped into a plane.



No. 152. Elevation of Tapering Pipe-Sleeve for Pitched Roof

Trap Ventilation. Needless multiplication of soil and vent connections is undesirable, but certain principles must be carried out to secure a perfect job. These have often been curtailed by the extremists of one class, and at expense of the quality of work. It is the extremists who regulate progress and keep things at a reasonable mean. The extremists in progression would drag us into practices perhaps unsafe; while their opposites, derisively termed "old fogies," hold us back, sometimes on untenable ground. The result is that the conservative element is the safest class to follow; it neither discards a well-tried method nor embraces a new one, without good reason to sustain the action.

As before intimated, the change in character of buildings and mode of life has necessitated a maze of pipe work in some buildings, which to the uninitiated looks like a senseless network thrust on the owner to the pecuniary gain of the plumber. This is not the case, as every plumber well knows; and he can easily disarm this type of creduality by being well versed in the philosophy of his business.

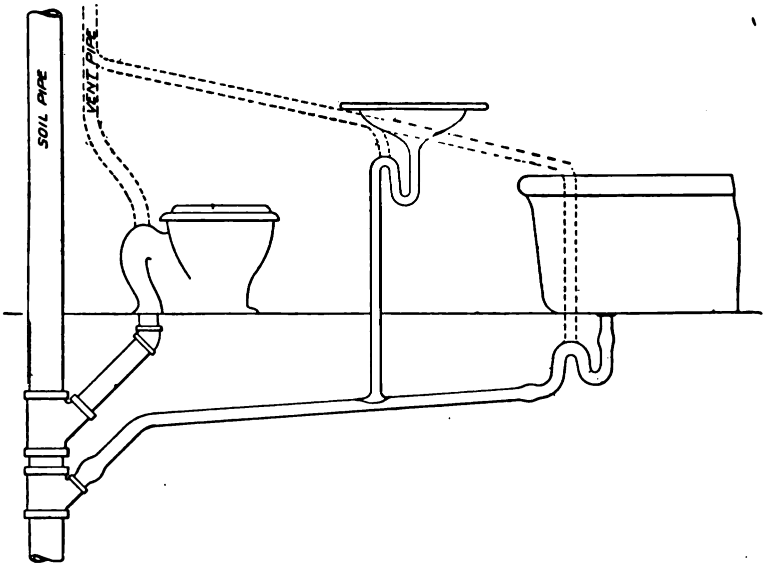


Fig. 153. Common Form of Crown and Stack Ventilation.

The familiar cry that crown ventilation* of traps destroys the seal by evaporation, is often but the echo of the voice of a man with an axe to grind. The deep-seal trap costs but a trifle more than the ordinary. There are also positive mechanical means—comparatively cheap, too—of protecting a vacant or unoccupied house against sewer air. In occupied houses, there is no chance for traps to lose the seal by evaporation; and, when properly piped, the evaporation of seals does not take place so fast as might be supposed. The crown vent is merely, or should be, to keep the water from being siphoned out of the trap. It is the practice of making the crown vent do duty not only as a siphon-preventer but also in the capacity of a stack vent, that has created the impression as to rapid evaporation.

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*There is an increasing disposition to substitute continuous ventilation for crown ventilation.

If we bring a branch waste to a fixture just as though it was to be a "dead-end" connection, and then put in a liberal crown vent continued to the roof, as shown in Fig. 153, we have filled the letter of most specifications, because we then have *crown ventilation* and *stack ventilation*. But this is not the spirit of the work specified, nor is it up to the standard of intelligent workmanship. The current to the roof passes up the trap leg, and thence through the crown vent directly to the open, being brought on its way in close proximity to the seal of the trap; and it is no cause for wonder that such a connection would

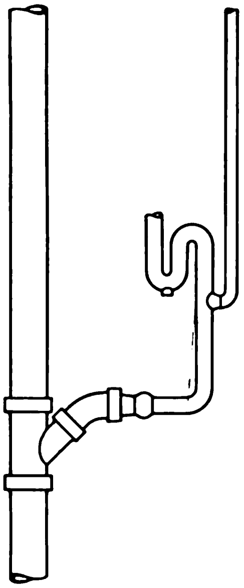


Fig. 154. Prevention of Siphoning Thwarted by Improper Placing of Vent Connection.

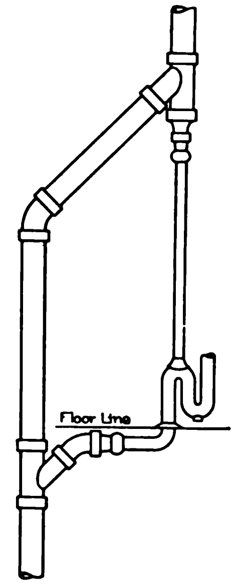


Fig. 155. Waste Stack Connected to Vent Stack above Highest Fixture.

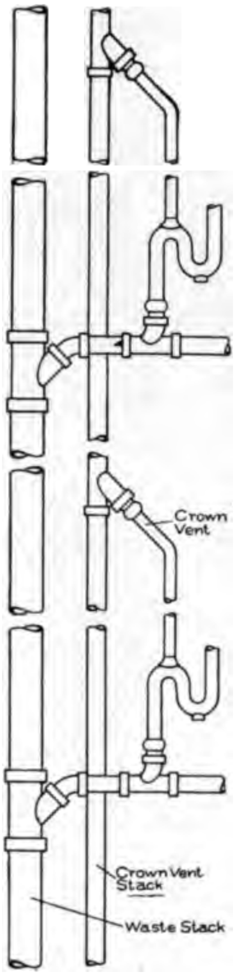


Fig. 156. Crown Vent Stack and Waste Stack Standing Close Together, Giving Loop Effect in Pipe Ventilation.

rob an ordinary trap of its seal within a surprisingly short time, if the fixture is left unused. This is the type of installation found in the wake of speculative builders, scrimping plumbing contractors, and ignorant or unscrupulous journeymen. Many examples of this double-duty vent pipe are seen, in which the workman foresaw the result to some extent; and, in attempting to counteract the supposed ills of evaporation, made the vent useless as a siphon-preventer by connecting the vent 10 inches or more below the crown of the trap, as shown in Fig 154. The proper way is to make both the waste and the crown vent branches from other lines. Of course, if it is the top fixture, or there is only one on the line, the waste stack may end in the beginning of the vent stack or connect into the vent stack, as in Fig. 155, according to circumstances. The main current goes by the most direct route —up the main waste and vent stacks of the string. If the crown vent and waste stacks stand close together, as in Fig. 156, we have the loop effect before spoken of; and with the fixtures near the stacks, the waste and crown-vent connections are both short—which is proper. It is poor practice to have the stacks far away from the fixtures, because one is then likely to fall into the error of allowing the crown vent to act also as a direct line vent for the branch waste. This plan is such a short-cut to accomplishing the work of roughing-in, that the temptation to err is great. If the waste stack cannot come near the fixture, then follow the loop principle, and turn up and into the vent stack, branching the trap into the waste branch, and taking the crown vent into the vent stack, as shown in Fig. 157, or into a vent continuation of the branch waste, as preferred. If neither main stack can come near the fixtures, then loop out from the soil or waste stack to the fixture, and back into the main vent, leaving enough upright

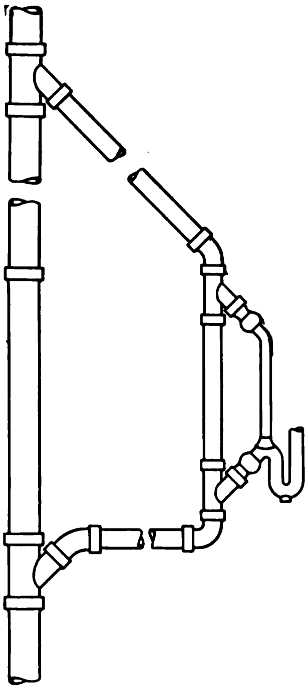


Fig. 157. Method of Securing Loop when Waste Stack is not Near Vent Stack.

pipe at the fixture end of each loop to branch the waste and crown vent into, as illustrated in Fig. 158. In this way, half of the branch loop acts as a waste, and half as a vent, and there is ventilation through the soil or waste branch part without continually pulling the air into juxtaposition with the trap seal. Also, the local branch waste to the trap and the crown vent pipe are thus permitted to be as short as desired.

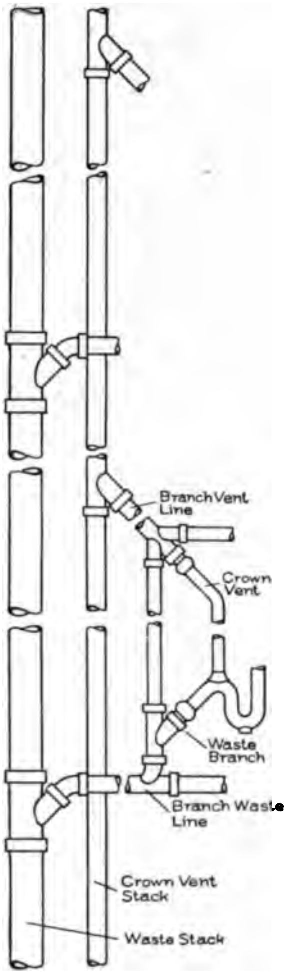


Fig. 158. Method of Ventilating Pipes where Neither Waste Stack nor Crown Vent Stack are Near the Fixture.

To avoid separate stacks for scattered fixtures, what is termed the *continuous system* of soil pipe is frequently employed when practicable. This means offsetting the main so as to be able to include all the fixtures of a toilet-room without making long branch wastes. If vent lines are also offset in this manner, some provision for water-washing the offset should be made, as the products of corrosion or other foreign matter might otherwise fall into and choke the bend at the foot of the upper vertical part. Especially is this true when plain wrought pipe is used. Lavatory wastes are generally used to wash vent lines in such cases.

Some city ordinances permit the continuous system practically without vents, merely requiring the fixture connections to be not over 3 feet in length, and requiring either vents or non-siphoning traps where the stack cannot be brought within reach of the 3-foot limit placed on branch connections.

A plan of offsetting, some modification of which may be used in any kind of system, is shown in Fig. 159, which makes plain the work of offsetting soil waste and vent lines without incurring the risk of having trouble with the vent pipe sooner or later. It provides for throwing the corrosion of the vent line, both above and below the offset, into the soil line, where it will be washed into the sewer by the water discharged from the closets and other fixtures. By simply offsetting the vent line, the corrosion from the pipe above the offset will fall into the bend, drift out into the horizontal part slightly, and finally choke up the horizontal vent altogether. As shown by the engraving, commencing with the main soil line at the first fixture, a branch line is made, and the *branch* then becomes the main soil line, leaving the vertical part for the vent. Next comes the offset, and after that another branch line for soil fixtures, again leaving the vertical pipe for the vent, so that whatever falls down the vent, either above or below the offset, lands in the soil pipe and is carried away with the water. With this arrangement, the only possible chance for the vent to clog with corrosion is in the horizontal part of the vent offset. What corrosion takes place in a piece of horizontal pipe, is not sufficient to warrant consideration in itself. There is no other corrosion to be taken care of, except that which forms in the few feet of vertical pipe between *A* and *B*, which will not be enough to restrict materially the area of the pipe. It is best to make the piece of pipe between *A* and *B* as short as possible.

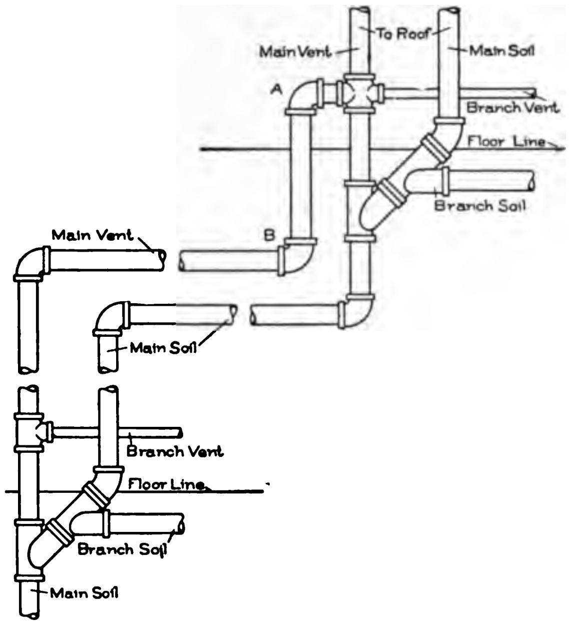


Fig. 159. Method of Offsetting Soil Waste and Vent Lines.

With the continuous system, several offsets, simple or more or less complex, as shown in Fig. 159, may be necessary in the same stack, according to location of fixtures and the scheme of venting and trapping. Fig. 153 shows a group of fixtures piped diametrically opposite to the continuous stack idea. The main stack does not deviate in favor of odd fixtures. Regular open wall-traps are used. The crown vents are assembled into one stack, and carried up independently or into the stack above the highest fixture. As before stated, the plan shown in Fig. 153 is faulty in that it favors evaporation of the trap seals by putting the extra duty of a line-vent current on the siphon or crown-vent branch.

Anti-siphon traps often simplify ventilation problems, especially in awkward situations where it would be very difficult to vent a fixture properly with pipe. Fig. 160 illustrates an example of this kind, in which non-siphoning traps are used on bath and lavatory without any form of crown or branch line vents. In good practice, bath traps are placed convenient to reach, having screw-top hand-hole with cover in full view at the floor-level.

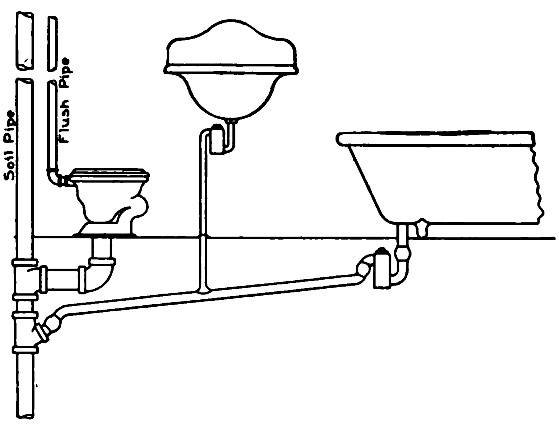


Fig. 160. Anti-Siphoning Traps Dispensing with Necessity for Vent Lines.

Soil Stacks. The size to make a soil stack is largely a matter of opinion. There are examples of 10-inch stacks serving 40 closets with the usual complement of lavatories and urinals. There are also instances where as many as 75 closets and numerous other fixtures all discharge into a 5-inch stack which has never given any indication of being too small. Although common usage requires a 4-inch soil stack, there seems little advantage in adhering to this dimension in small and simple installations. When the plumbing was designed for the city of Pullman, Ill., more than twenty years ago, 3-inch soil stacks were used for small dwellings, and in some cases they were placed in a party wall, so as to afford service for two adjoining houses. The plumbing regulations of Washington, D. C., have allowed for some years past the construction of 3-inch soil stacks for dwellings having only a single bathroom, and the practice has been justified by favorable results. When it is considered that the outlet of a closet is rarely more than 2½ inches in diameter, it appears that a size smaller than 4 inches is often allowable.

The size does not increase with the number of fixtures. Very few of a hundred closets in a building would ordinarily be flushed simultaneously. A 5-inch stack would answer well for 100 closets in a tall building where the toilet-rooms are superimposed, as shown in Fig. 161, which outlines the soil, waste, and vent pipes of several groups of fixtures, rain-water leaders, etc. If the same number of closets were at one elevation, and the fall only moderate, common sense would dictate a 6, 8, or 10-inch line, with 4-inch fixture branches.

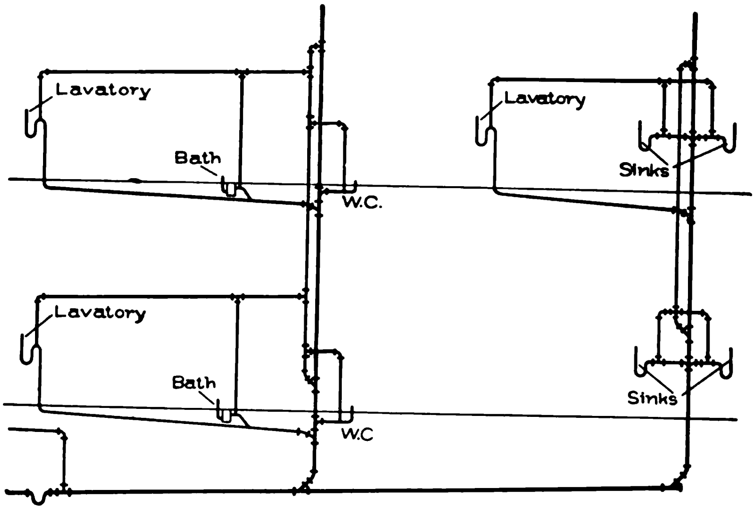
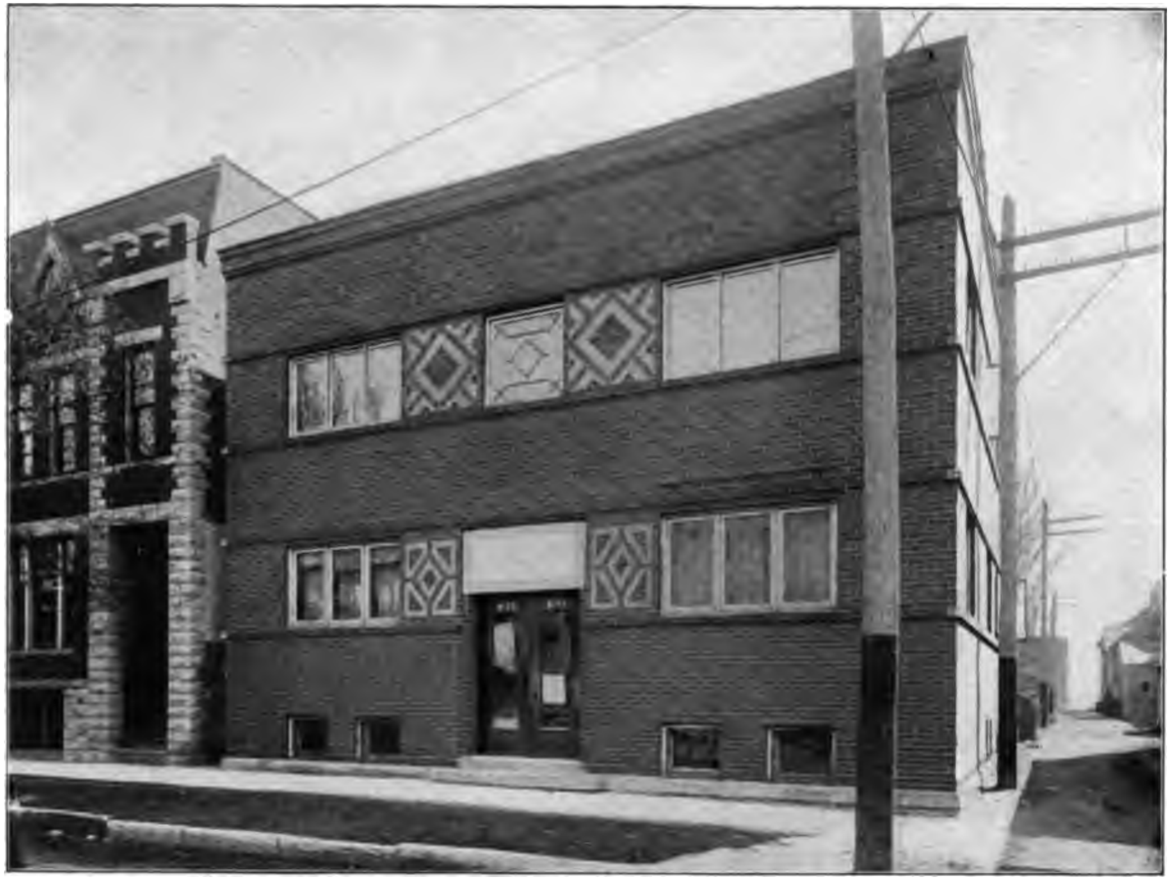


Fig. 161. Showing Layout of Soil, Waste, and Vent Pipes of Several Groups of Superimposed Fixtures in Same Building.

The velocity with which the water will flow away should be a prime factor, but sizes in soil and waste pipes are far more a matter of empiricism than in supply work. A soil pipe not too large is self-scouring in a sense. This point is erroneously argued in favor of small waste pipes. If a soil pipe too small for the duty should be installed, ordinary usage would develop the fact quickly. But in a waste outlet, where grease is likely to accompany the water, a pipe



A WELL PLANNED FOUR-FLAT BUILDING, CHICAGO, ILLINOIS

R C. Spencer, Jr., Architect, Chicago

Walls of red paving brick; pattern of red and gray brick. In each apartment is a buffet kitchen; the two bedrooms with connecting bathroom are laid out so as to form a separate suite giving the much desired privacy so generally lacking in flat construction. Cost, $8,500.

large enough to carry the waste easily when the pipe is new, may become choked after a considerable period of time, and merely because it is of the size so-called "self-scouring." A house line which may be much too large for the waste will be likely to choke from floating matter adhering to the sides above the water line until overhanging ridges are formed that break down in the channel. Being too heavy for the water to push along, this matter acts as a dam, and complete stoppage soon results. This is why large sewers are built with elliptical bottom section. Having variable flows to take care of, the depth of water produced by ordinary usage cleanses the conduit, and keeps it in much better condition than if round conduits of the same capacity were employed.

Slope. With due respect for appearance, all the fall possible should be given lateral soil and waste lines. About $\frac{3}{16}$ inch to the foot (one degree) is taken as the minimum. With cast pipe and leaded joints, much more than this can be given, by gaining change of direction in setting the joints. With screwed fittings for wrought pipe, tapped, pitched one degree from the nominal angle, less latitude to vary the fall is offered. Considerable variation is possible, however, by cutting pitched threads on the pipe. In positions where the cutting of one pitched thread entails the work of cutting another with the pitch just opposite that of the first in order to follow the perpendicular again, the work is irksome and is seldom resorted to. Cast fittings, threaded, for drainage work, are recessed in the ends, so that, when screwed on the pipe, the pipe and interior of the fitting are of the same diameter, thus presenting no jog or broken edges to favor stoppage. Stoppage of drains of any kind is likely from many causes; and during installation, trap-screw ferrules, or tees with brass plugs, according to the kind of pipe being used, should be provided along the line, as

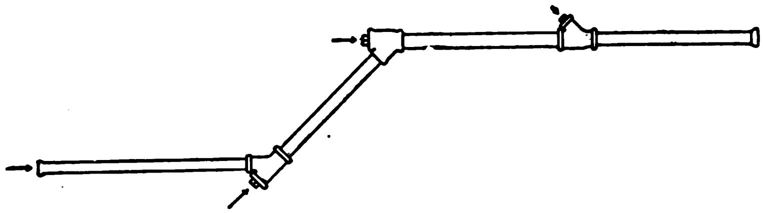


Fig. 162. Trap-Screw Ferrules Installed at Intervals to Facilitate Cleaning of Drain Pipe.

shown in Fig. 162, so as to make the work of cleansing as convenient and inexpensive as possible.

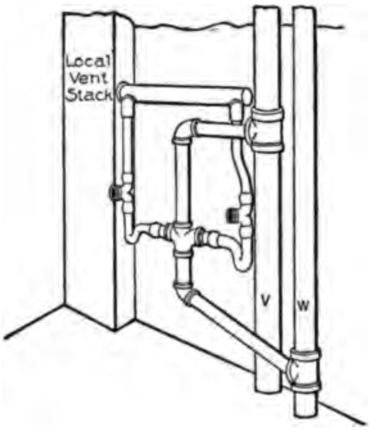


Fig. 163. Local Ventilation for Two Urinals.

Sizes of Soil and Waste Pipe. The usual sizes for soil and waste work are: 5-inch for ordinary house main (horizontal); 4-inch for 1 to 4 closets; 5-inch horizontal branch from 5-inch stack for a battery of five or more closets; 5-inch stack for any ordinary number of fixtures; main vent stack, same size as soil-stack; loop vent, same size as stack; crown-vent stacks, 2 or 3-inch; slop-sink stacks, 3 or 4-inch; closet connection, 4-inch; closet crown vent, 2-inch; slop-sink connection, 3-inch; slop-sink vent, 2-inch; urinal stacks, 3-inch; urinal branch wastes, 2-inch; urinal trap vents, 1½ to 2-inch; bath stacks, 3-inch; bath-waste connection, 2-inch; lavatory wastes, 2-inch. The 2-inch refers to the size of cast pipe used in the case of lavatories and baths; the lead trap and connections of these, and often of other fixtures, are made 1½-inch. Small lavatories often have 1¼-inch waste. The crown vent is usually one size less than the trap for all but closets and slop sinks. Of late, bath-waste outlets are frequently made 2-inch. Kitchen-sink stacks are made 3-inch; single sinks or branch waste for one sink or set of trays, 2-inch, with 2-inch trap and 1½-inch crown vent.

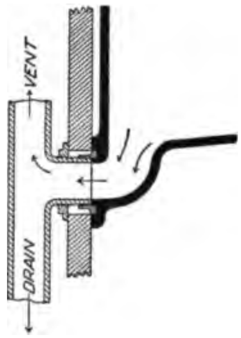


Fig. 164. Part Section of Locally Vented Urinal and Connection.

Local Ventilation. A local vent is a pipe leading air from the bowl of a closet or through the outlet of a urinal to carry away odors with a current of air fed by the air of the room. In Fig. 163 are shown two openings for urinals where the roughing-in provides for local ventilation for the urinal bowls in a way that is equivalent to the local vent pipe to a closet bowl. *V* is a general vent stack, and *W* the urinal waste stack. Instead of putting in crown vents for the traps, the branch waste becomes a vent at the junction of the trap branches, and loops back into the general vent stack. There is sufficient ventilation in this case for two reasons—the traps are close to the line; and the current up the main local vent stack is induced and maintained by a fan motor, which, in drawing the odors from the urinal bowl, creates more or less suction on the house side of the trap seals and counteracts the tendency toward siphonage on the sewer side. The roughing-in shown, is hid by marble slabs in the finished work.

A section of the marble back, with urinal and vent and waste connection, is shown in Fig. 164, which makes clear what is meant by local urinal ventilation. The difference between it and local closet ventilation, is that as the trap for the urinal is not in the urinal proper, the current from the room passes through the urinal outlet except while it is flushing; while in the closet the local vent connection is made to the bowl above the visible water-level, because the trap below interferes with connecting it otherwise.

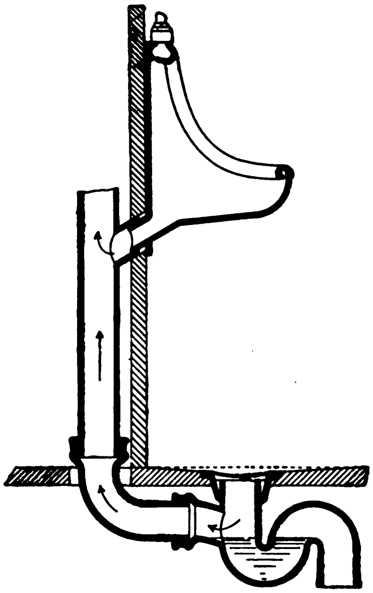


Fig. 165. Locally Vented Trap for Urinal and Floor Drain Combined.

Another plan of local-venting a urinal is shown in Fig. 165, in which the urinal trap answers as a trap to the floor drain as well, and the local-vent current passes down through the grating of the floor-slab drain and up through the urinal waste to the point where the urinal proper connects. Between the trap and urinal connection, the pipe is a waste and local vent combined, its continuation above the urinal vent connection being simply a local vent pipe, the area of which being equal to the combined area of the urinal outlet and floor-slab grating, a current also passes from the urinal bowl through its outlet into the local vent pipe. The only fault to be found with this arrangement is the abnormal distance of the trap from the fixture, which, however, is of little consequence so long as the means for producing a current in the local vent stack is doing its duty. Fig. 166 shows the openings left for a battery of closets that are to be set on a

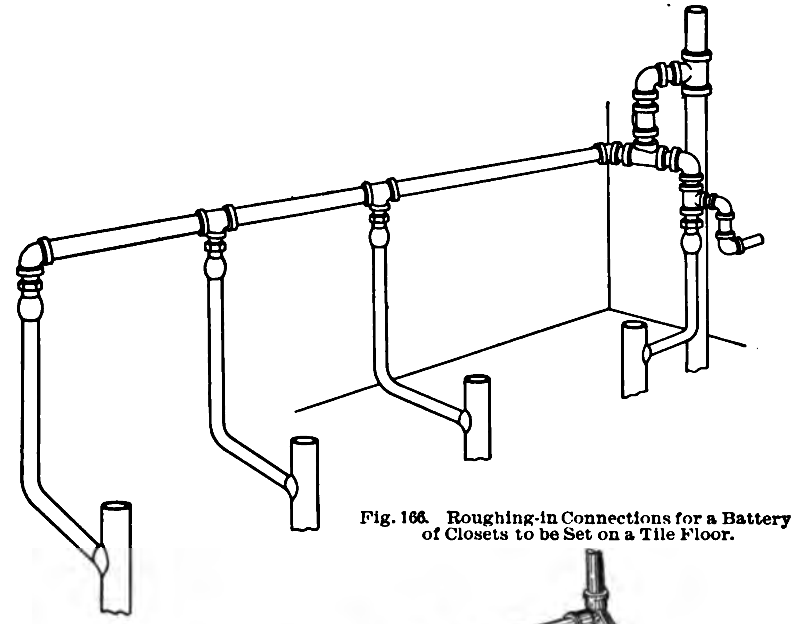


Fig. 166. Roughing-in Connections for a Battery of Closets to be Set on a Tile Floor.

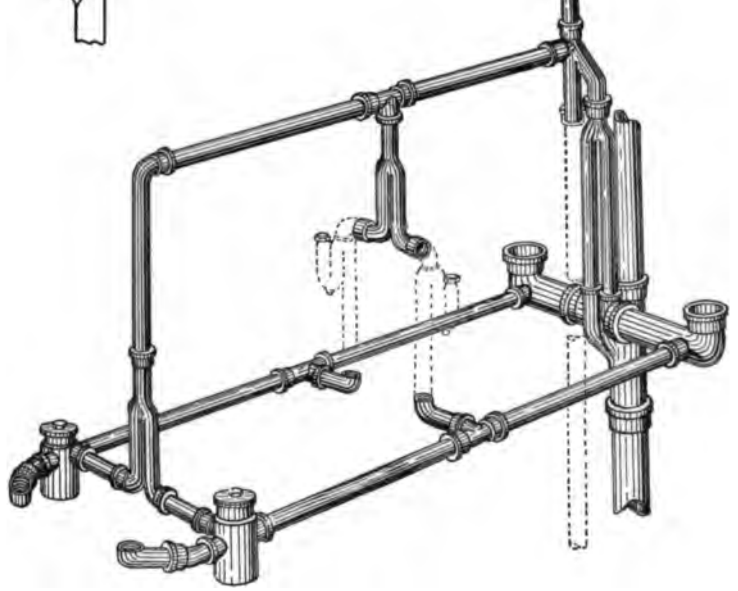


Fig. 167. Roughing-in for Adjacent Toilet-Rooms on Same Floor of Double-Flat Building.

tile floor. The uprights connect into a branch soil line below. The illustration is given to show a system of venting which can be used with closets that do not permit of crown venting.

Local vent stacks are round or rectangular, and are made of galvanized sheet iron. Unlike the soil or supply pipe system, the stack system is made proportional; that is, the area of the stack at any point is an approximation to the aggregate area of all the vent branches that have been connected into it up to that point. The local vent stack is sometimes carried into the same shaft which incloses the smoke-pipe from the boilers. In other cases it is connected

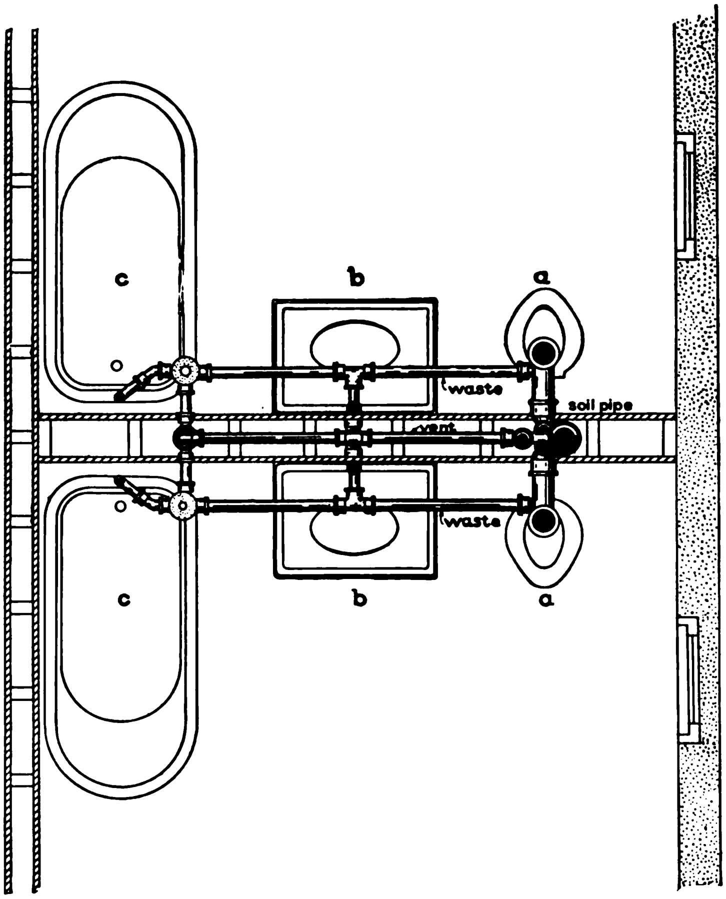


Fig. 168. Plan of Complete Installation Shown in Part in Fig. 167.

with an exhaust fan driven by power, usually supplied by an electric motor, thus insuring a constant air-current. Bowl or local ventilation is not generally installed in dwellings. The closet does not receive such frequent usage in private houses as in larger buildings such as hotels, offices, etc.; and in the smaller structures there is no hot flue that can be depended upon for purposes of aspiration. If led to the open air, the vent will act very well in warm weather; but during the winter months it will be likely, through reversal of the current, to bring in cold air and disseminate the odor through the apartment.

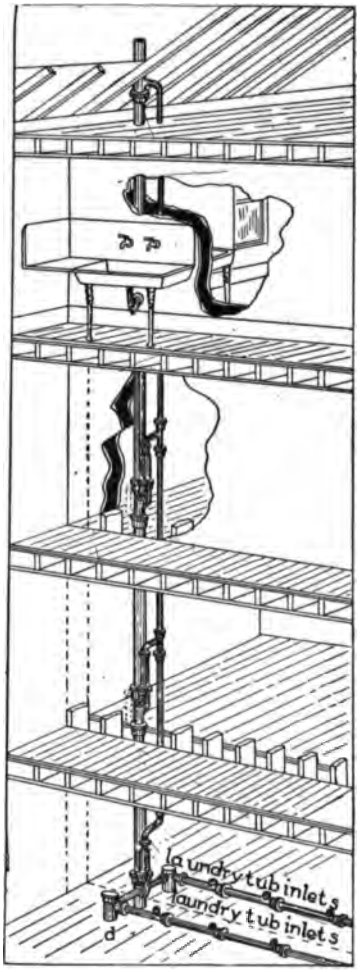


Fig. 169. Broken General View of Waste and Vent Stacks for Laundries and Kitchen Sinks of a Flat Building.

Soil Pipe and Fittings. Under the head of *specialties*, many forms of patented soil-pipe traps and fittings have been placed on the market from time to time, with a view to lessening labor and cost and simplifying the work of roughing-in for plumbing fixtures. Of these, a singular instance of the use of one type will be noticed. Fig. 167 illustrates a well-known line used in roughing-in for the toilet-rooms of a double-flat building. Being drawn in perspective, the function and merit of every fitting shown is self-evident. Fig. 168 gives in plan view the roughing-in shown in Fig. 167. The location of the fixtures on the floor below the plan of piping, is indicated in solid lines by *a*, *b*, and *c*. On other floors, corresponding fixtures for the stack shown, are of course superimposed as a matter of economy and convenience. Fig. 169 is a broken general view of the waste and vent stacks for the laundries and kitchen sinks of the same building, the roughing-in work and some of the fixtures being shown. The regular standard soil-pipe and fittings can be made to answer for any case, although inconvenience and additional expense are often incurred in working fittings of standard dimensions in close quarters.

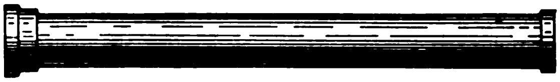


Fig. 170. Single-Hub Length of Standard Soil-Pipe.

Fig. 171. Double-Hub Length of Standard Soil-Pipe.

There are several weights of soil pipe and fittings used, varying with the building or with the requirements of city or state sanitary laws, etc. The weight known as *standard* is sometimes used on buildings under four stories in height, and for vent pipes and soil-pipe extensions above the highest fixture. Extra heavy pipe and fittings are used in tall buildings and in most ordinary work, for all soil and waste purposes below the highest fixture. The standard length of soil pipe for all diameters, is five feet, exclusive of hub.

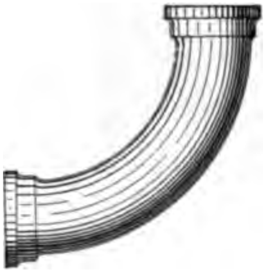


Fig. 172. Quarter-Bend, with Double Hub.

Fig. 170 shows a regular single-hub length. Fig. 171 represents the double-hub length employed to avoid the use of double-hub fittings and extra joints where less than full lengths are required in cases where the cost of regular extension pieces would exceed the price of double-hub pipe. Fig. 172 is a quarter-bend with double hub. It is of the long-sweep or long-radius pattern. The whole list of standard regular fittings is made in the long-radius pattern. They

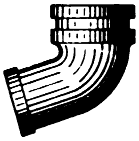


Fig. 173.

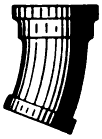


Fig. 174.

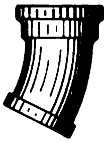


Fig. 175.

Short-Radius Bends for Soil-Pipe.

should be used where possible; but the shorter-radius type, corresponding to that shown in Figs. 173 to 180, is most generally employed because the little room available enables the plumber to lay lines in places where cramped conditions make the use of the long radius impossible.

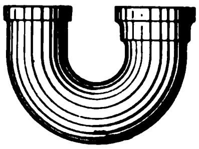


Fig. 176. Return Bend for Cast Soil-Pipe.

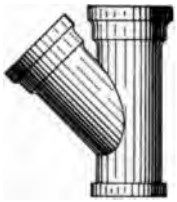


Fig. 177. Single Y.

One-sixteenth, one-eighth, one-sixth, one-fourth, and return bends embrace the regular list of soil-pipe bends, giving a range in angles from 22½ to 180 degrees in the same plane; and, by winding them, giving a twist to the joints, almost any angle with the original direction can be obtained.

A wider range of bends is offered in the recessed and threaded cast-iron drainage fittings for use with wrought pipe. Omitting the *pitched* ells and tees for regular fall, 5⅝ degrees is the most obtuse fitting regularly made.

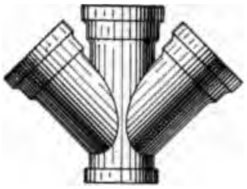


Fig. 178. Double Y-Branch.

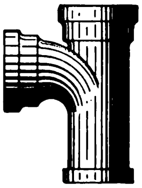


Fig. 179. Sanitary Tee.

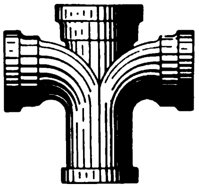


Fig. 180. Double Sanitary Tee.

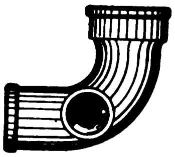


Fig. 181. Quarter-Bend with Side "Outlet."

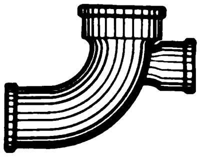


Fig. 182. Quarter-Bend with Heel "Outlet."

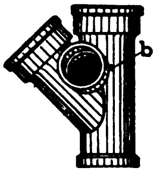


Fig. 183. Single Y with Side "Outlet."

The return bend for cast soil-pipe is represented by Fig. 176; single Y, by Fig. 177; double Y-branch, by Fig. 178; sanitary tee, by Fig. 179; and the double sanitary tee, by Fig. 180. The tee and double tee shown are known as the *sanitary* pattern, on account of the curved branches, which direct the flow in the pipe line somewhat in the same manner as does a Y-connection. Common tees and crosses are made in strictly right-angle branches. The ¼-bend is also made with right and left side-outlet, as indicated by Fig. 181; and with heel-outlet, as shown in Fig. 182. Tees, crosses, and Y's can be had with side outlet as shown at *b*, Fig. 183. These auxiliary openings, while always termed *outlets* by the trade, are in fact *inlet* branches. Long branch fittings, with a branch equivalent to a Y and ⅛-bend connection, are also made.

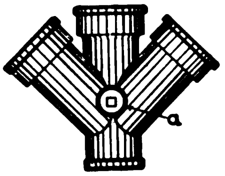


Fig. 184. Double Y-Branch with Trap-Screw Clean-Out.

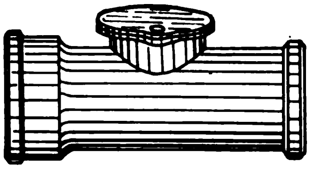


Fig. 185. Bolted-Plate Clean-Out on Soil-Pipe.

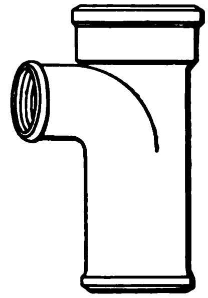


Fig. 186. Cast Soil-Pipe with Threaded Branch to Connect to Wrought Pipe.

Offsets may be had to offset the pipe as little as half of one diameter, and up to six diameters. Any of the standard branches can be had with trap-screw clean-out, as shown at *a*, Fig. 184. The bolted-plate clean-out, indicated in Fig. 185, is undesirable, as the cover can rarely be securely replaced when removed for purposes of cleaning. A series of cast soil-pipe fittings are made with branches threaded for wrought pipe, as shown in Fig. 186. These meet the demand for a means of easily connecting wrought vent-pipes to a cast-iron pipe line. Similarly, combination lead and brass soldering nipples threaded for wrought pipe are now carried by supply houses, the lead being furnished straight, as shown in Fig. 187, or in the form of a quarter-bend. These are very convenient for use with wrought vents, and are equivalent to the regular combination lead and iron

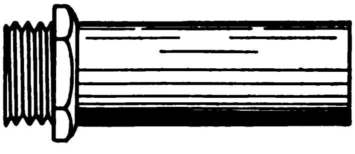


Fig. 187. Combination Lead and Brass Soldering Nipple Threaded for Wrought Pipe.

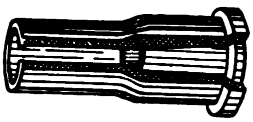


Fig. 188. Combination Lead and Iron Ferrule, "Raymond" Type.

ferrule, shown in Fig. 188, which can be used with cast pipe by calking-in. This combination ferrule, the "Raymond", is often prohibited as it is sometimes damaged during the process of calking; and sometimes the outer covering is burned through in running the joint. Some lead is generally desirable in a fixture connection as it is the surest means of providing shrinkage and settling. The lead should be surrounded with a sheet-metal (iron) band in a way to prevent rats and mice from knawing through the lead.

Brass ferrules for calking-in make a better job than lead and iron; when used, a piece of lead should be wiped on, which is often inconvenient; and both ferrule and work are more expensive.

The recessed or hub ferrule shown at *b*, Fig. 189, is a good form, but the stock length brings the increase in diameter necessary for the recess close to the face of the hub of the fitting, making it very difficult to yarn and calk, even before the lead pipe is wiped on; and as these joints are usually wiped before the ferrule is calked in place, it is difficult to make safe joints where they are used. The forms of brass ferrule generally used are shown at *c* and *e*, Fig. 189, the lead end of *e* being contracted for use with $1\frac{1}{2}$-inch pipe or less.

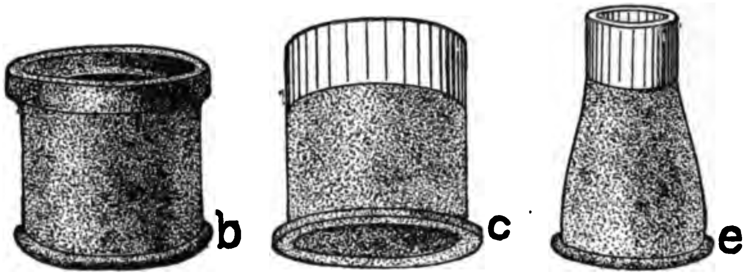


Fig. 189. Brass Ferrules—*b*, Recessed or Hub; *c*, Straight; *e*, with Lead End Contracted to Make Joint with Smaller Pipe

Soil-Pipe Joints. A section of a soil-pipe joint is shown in Fig. 190. The materials used in making these joints are good, clean hemp or oakum, with melted lead poured in and afterward calked. The packing to support the lead should be of uniform strand, evenly twisted. When a joint is made with pipe cut to length, the bead having been cut off the spigot end, care must be taken to pack the yarn uniformly tight without driving it through into the bore of the pipe, and in a way to keep the spigot end in the center of the hub space so as to get a uniform thickness of lead on all sides. As an extra precaution in difficult places, the packing is sometimes dipped in linseed oil, and then wrung as dry as possible, before yarning a joint. This gives almost positive assurance that the joint will not leak water. Likewise, shavings of sperm candle whittled in on top of the yarn before pouring the lead, prevent water leakage.

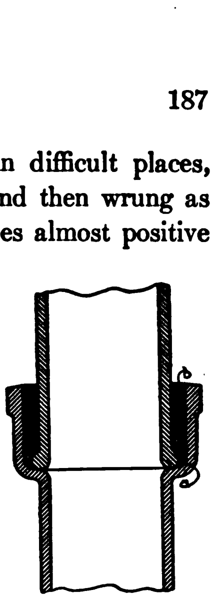


Fig. 190. Section of Soil-Pipe Calked Joint.

Some plumbers pour in just enough lead to make a ring around, and calk it down reasonably tight on top of the yarn, before pouring the hub full. Unless very little yarn is used, this does not leave a solid ring of lead deep enough to insure the best joint; and if too little yarn is employed, there is danger of the lead burning its way through into the pipe. This method is therefore undesirable in either case.

Care should be taken before pouring a joint, to see that no threads of yarn are standing above the face of the hub; otherwise a leak may result from stray threads protruding. Becoming charred by the heat of the lead, they soon leave a tiny hole through the lead, from which trouble results. No matter what the position of the joint, the entire charge of lead to complete it should be poured at one time, and the lead should be hot enough to insure a true union of the meeting edges. If the pipe is large or the weather very cold, it is better to warm the hub in order to insure the flowing edges uniting, than to risk pouring the lead so hot that it may burn through the packing.

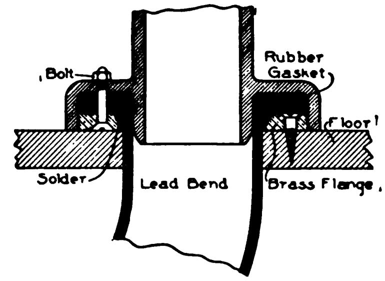


Fig. 191. Good Type of Closet Floor-Joint.

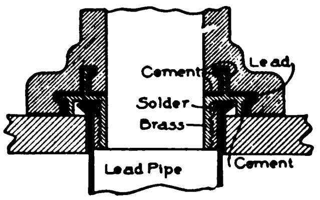


Fig. 192. Secure Type of Floor-Joint, for Closets which can be Revolved about the Outlet.

It is a matter of opinion, whether or not a joint should always be calked while it is hot. If the pipe is heavy enough to stand it without cracking the hub, it can make little difference whether the joint is calked hot or cold. If the pipe is light, a hard calking while the joint is hot and the hub expanded may cause splitting of the hub when it contracts from cooling. The best plan appears to be that of driving down the lead reasonably tight while it is hot and therefore softer than when cold, at which time it will give and adjust itself to the irregularities of the hub and spigot. Then, a little later, calk twice around with a thin-edge tool, driving the lead into contact with the spigot surface on one edge, and against the inner hub surface on the other.

Floor Joints. A closet floor joint of good type is shown in Fig. 191. In this joint, a bevel-edged brass floor-plate is screwed to the floor and well soldered to the end of the lead bend, as indicated. The floor-plate has slots for the closet bolts, so that any variation in the position of the bolt holes in the flange of the closet pedestal will not cause trouble when aligning the bolts, as they can be slid along in the slots of the plate to the required position. Common putty, plaster of Paris, or hydraulic cement may be used instead of a rubber gasket; but the latter two materials make it difficult to remove the closet from its setting, and there is always risk of breaking the flange if the pedestal has to be moved for any reason.

A secure type of joint, introduced a few years since, is shown in Fig. 192. This connection is well suited for such types of closets as can be revolved about the outlet, but cannot be used with closets where the outlet is well toward the rear of the fixture

TRAPS

Traps are made in many forms, none of which combines every desirable feature. A trap with vertical drop at the inlet is considered best for the main intercepting trap, as it allows the incoming water to break up the scum and floating matter so that it will be carried out promptly by the flow. This form also presents a difficult place for sewer rats to climb, and is therefore favored for that reason also.

In regular fixture traps, open-neck bends, and the least surface possible, are favored. The Y and $\frac{1}{8}$-bend connections in one fitting, and other fittings combining the virtues of the open bends of long-radius fittings, are used merely because they offer little chance of stoppage; but traps should have every part exposed to view in order to betray leakage. Tide-water traps are usually nothing more than simple, large, swinging check-valves. Some intercepting traps are provided with a swinging check. The tide-water feature is necessary only when high water or tides are likely to raise the water into which the sewer discharges so as to flood the cellar through fixture openings.

Siphonage. Traps introduce into plumbing the element of *siphonage.* This may be normal and desirable, as in the case of closets which discharge their contents by siphonic action, but undesired siphonage in fixture traps, and the means of preventing it, are prime factors in every plumber's work.

Ordinary siphonage can best be illustrated by a few simple diagrams showing the principles involved. In Fig. 193 is shown a U-tube with legs of equal length, filled with water. If we invert the tube, as shown in Fig. 194, the water will not run out, because the legs are of equal length, and contain equal weights of water, which will pull downward from the top with the same force, tending to form a vacuum at *A*. Cohesion of the particles of water, together with equal atmospheric support of the water at the open ends of the tube, prevents any appreciable void space when the U is of short length. If one of the legs is lengthened, as in Fig. 195, so that the column of water is heavier on one side than on the other, the water will run out. The atmospheric pressure being practically equal on both legs, the greater weight of the water in the long end, through cohesion, pulls the water in the shorter tube up over the bend, in much the same way as an unbalanced chain would run over a pulley. The columns

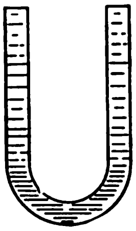


Fig. 193. U-Tube with Legs of Equal Length.

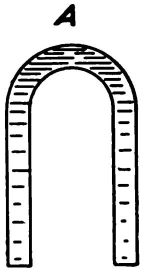


Fig. 194. U-Tube Inverted.

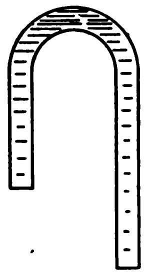


Fig. 195. Inverted U-Tube with Legs of Unequal Length.

of water in the tube in this case may be likened to a piece of rope hanging over a pulley; when equal lengths hang on each side, it will remain stationary; but if one end is longer and therefore heavier than the other, the whole rope will be drawn over by the longer and heavier portion.

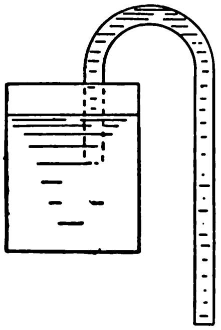


Fig. 196. A Common Siphon.

If the short leg of Fig. 195 be dipped in a vessel of water, as shown in Fig. 196, we then have the conditions necessary to form a common siphon. The atmospheric pressure, which before acted on the water at the bottom of the short leg of the tube, now becomes operative on the surface of the water in the vessel, and the flow through the tube will continue until the water-level in the vessel falls slightly below the end of the tube, admitting air and breaking the siphonic action. Gravity acts proportionally on the water of both legs of the U during siphonage, and the point of tension is therefore at the highest point of the bend.

If the bend should be pierced at the top, air-pressure would be established at both ends of each leg, and gravity would instantly empty the short leg into the vessel. It is in this manner that a crown vent to a common fixture trap breaks the flow and throws enough water back into the body of the trap to preserve the water-seal. Fig. 197 shows the principle of Fig. 196 applied to the trap of a plumbing fixture. If the bowl is well filled with water, so that when the stopper

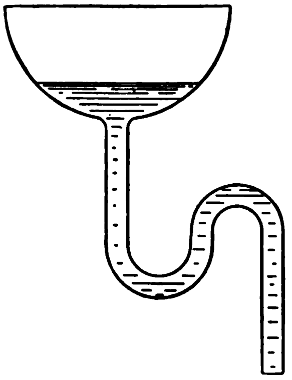


Fig. 197. Trap Fulfilling Siphonage Conditions.

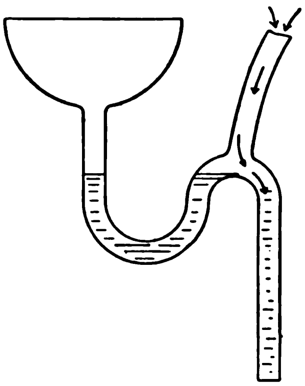


Fig. 198. Siphoning of Trap Broken by Crown Vent.

is removed from the bottom, the waste pipe for some distance below the trap will be filled with a solid column of water, siphonic action like that just described will take place and the trap will be drained. A sufficient amount of water runs down from the fixture and sides of the pipe above the trap to partially provide for the seal, its full restoration being assured when a crown vent is used, by water being thrown back from the short leg of the siphon (center leg of the trap) as shown in Fig. 198.

The direct action of the water of a fixture in breaking its own trap seal by siphonage, is called *self-siphonage.* A more common form of trap siphonage in defective work, is where two or more fixtures connect with the same waste pipe, as shown in Fig. 199. In such cases, the seal of the lower fixture is more apt to be broken by the discharge of the upper. The falling column of water leaves behind it a partial vacuum in the soil pipe; and the outer air tends to rush into the pipe through the way of least resistance, which is often through the trap seal of the fixture below The friction of the rough sides of a tall soil-pipe, even though it be open at the roof, opposed to the flow of air through it, will sometimes offer more resistance than the trap seals of the fixtures, with the result that the seals are broken, and gases from the drain are free to enter the building.

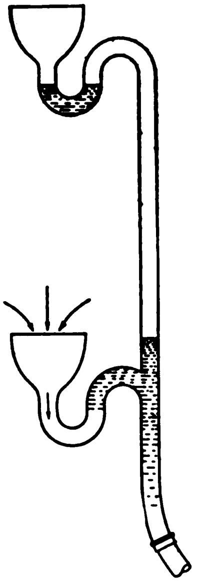


Fig. 199. Two Unvented Fixtures Connected to Same Waste Pipe, Causing Self-Siphonage.

Kinds of Traps. The kinds of fixture traps are innumerable. They can be divided into two general classes—those that seal with *water only,* and those that have a *mechanical seal* as an adjunct to that of the water. These may be again divided into *plain* and *anti-siphoning* classes.

The trap having no concealed partitions and with all its walls exposed to view, is best. If the water leaks through the wall, its defectiveness is evident, and the annoyance from the leak suggests repairing.

Of the simple *water-seal* fixture traps, the open-walled *drawn lead* is used for ordinary work. It can be had with equal-length arms or with extended inlet or outlet, so as to reach from fixture to floor or wall without a piece of intermediate pipe. The form shown by full lines in Fig. 200 represents a full "S" pattern. When the ends are bent as per dotted lines *A* and *C*, the trap is called a *running* trap; when the ends are at *D* and *C*, it is said to be a *half-S* or *P* trap; when the ends are set as at *D* and *E*, it is called a ¾-*S* trap. *F* is a clean-out screw for emptying and cleansing. The distance represented by *X* should, in a trap for ordinary purposes, be ½ to 2 inches, according to size. Frequently this distance, which constitutes the water-lock, is much reduced; and sometimes the trap is unsealed by the plumber stretching its bends in order to reach some faulty roughing-in.

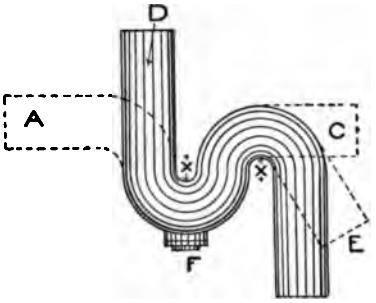


Fig. 200. "S"-Pattern Trap.

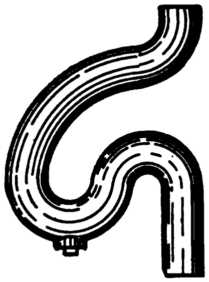


Fig. 201. A Bag Trap.

In buildings where the plumbing may be left unused for weeks from time to time, as is likely in rented houses, *deep-seal* traps, or those with mechanical seals also, should be used. This point is not so important in detached houses or those rented to one family only at a time, since, when a family moves out, there is no one to suffer. But in flat buildings, where some of the flats may be vacant for a time sufficient for an ordinary seal to be broken while other families are living in the house, deep-seal traps are more essential.

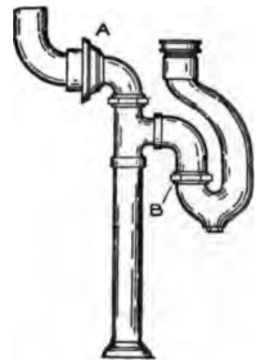


Fig. 202. Open-Wall Trap, Partly Cast.

Fig. 201 shows what is termed a *bag trap*, made to bring the inlet and outlet in the same vertical line. These traps are interchangeable with any others with straight-line outlet—for instance, as shown in Fig. 204.

An open-wall trap partly cast and partly tubing, generally made

of brass, is shown in Fig. 202, the vent connection to wall being at *A*. This form of trap generally has a swivel-joint at *B*, which is below the water line, so that the body may be swiveled to meet roughing-in openings in any direction within two diameters of the line of fixture outlet. The bag form shown is most convenient for D-shape or standing waste bowls which present the outlet comparatively near the wall. The regular "S" of this type suits bowls with center outlet, and will reach a wider range of variation in roughing-in.

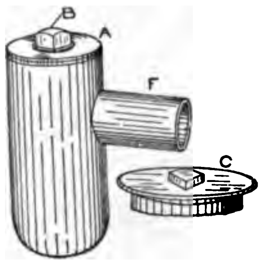


Fig. 203. Common Lead Drum or Pot Trap.

Fig. 203 shows a common lead drum or pot trap, most convenient to the plumber. It is furnished without openings, and the plumber makes bends, and wipes-in his inlet and outlet at points in the circumference most convenient to reach the fixture opening. *A* is the screw-top clean-out; and *B*, the wrench-face for turning it. The trap is furnished, when desired, with nickel-plated brass flanged cover, as shown at *C*, to screw on at the floor-level. *F* is ordinarily the outlet, the inlet being wiped-in near the bottom to give it the water-lock. This is not proper, however, as it puts the sewer air against the clean-out cover, which might leak gases into the building without betraying any evidence of its defectiveness by water leakage. To be strictly correct, *F* should be the inlet; and the outlet, in the shape of an offset, or that of an inverted P-trap without the trap-screw, should be wiped-in near the bottom in a way to retain the proper seal and thus bring the sewer air against the water-seal instead of the clean-out cover.

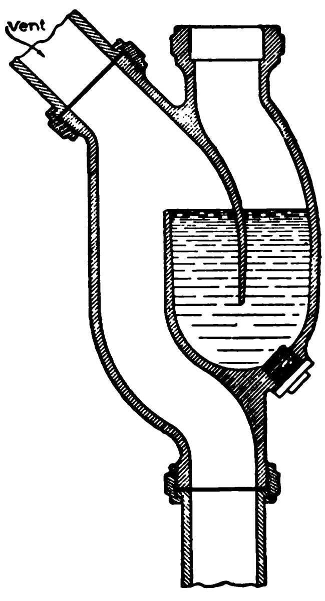


Fig. 204. Section of Flask or Atlas Trap, with Two Interior Weirs.

Traps that retain their seals by means of interior weirs are of doubtful character, even at their best; none but well-tested cast-brass traps of such a pattern should ever be installed. Fig. 204 is a section of a *flask* or *Atlas* trap, with vent, usually made of cast brass and depending upon two interior weirs to form the seal, one retaining the water, and the other dipping into the water to prevent sewer air from getting into the house through the fixture. If the water weir of such a trap becomes defective, there is no evidence except odors by which the occupants may discover it. If the dipping weir is defective the value of the water seal is *nil.* In either case the trap is no barrier to the admission of drain air to the house.

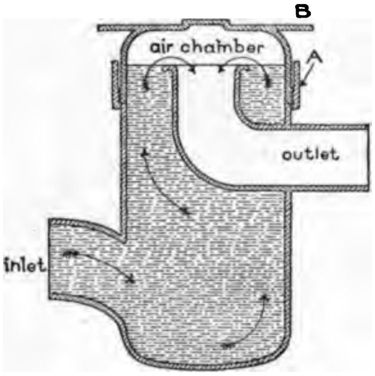


Fig. 205. Bath Trap with Submerged Inlet.

Fig. 205 illustrates a form of trap suitable for use with baths. It has a submerged inlet connection which is expanded so that the flow enters the trap at a dipping angle which produces a swirl with cleansing effect. The extension collar *A* is made so that the screw-cover *B* forms the gasket joint below the water-level. The method of providing the outlet in this trap makes it open to the same objection raised in connection with Fig. 203. This form, however, has the merit of being accessible for inspection without disturbing its service, which is impossible with the flask pattern shown in Fig. 204.

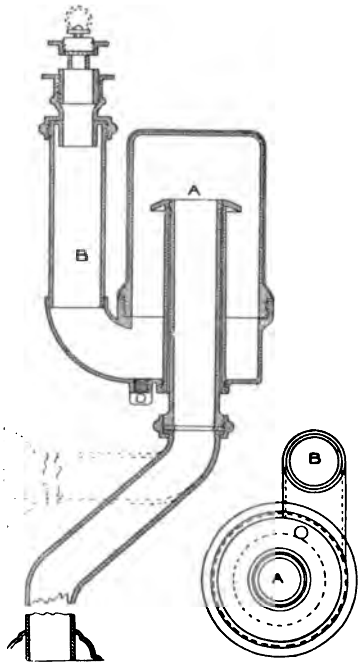


Fig. 206. Lavatory Trap with Interior Flanged Weir. Weir is Double-Walled to Betray Leakage.

The lavatory trap shown in Fig. 206, has an interior weir as shown at *A*; but the wall is doubled in such a way as to betray defectiveness by water leakage. It is made of cast metal, and is furnished with either glass or metal dome. The strong point claimed for this trap is the cleansing effect obtained by the flange extension of the exit, as shown at *A*, deflecting some of the water, which, together with the swirling effect produced by the tangential inlet, makes the trap self-cleansing.

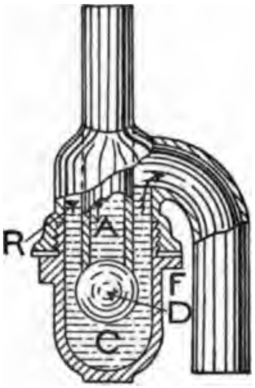


Fig. 207. Trap with Mechanical Seal Acting by Flotation.

Of the traps having a mechanical seal supplementing the water-lock, Fig. 207 is a specific type. The mechanical valve *D* is a rubber ball, lighter than an equal bulk of water, playing in the cup *C*. It acts by flotation, and presses up against the inlet *A* with a force equal to the difference in weight of the ball and the water it displaces. The body is generally made of lead; and the cup of glass, with screw-joint and gasket at *F*. This trap is proof against backwater; and, in case the waste line becomes choked below, will prevent a fixture from flooding even when others are discharged at a higher level. It has, however, several faults that counterbalance its merits. The inlet is open to the same criticisms that an interior wall of any other trap would be; the annular space at *R* accumulates filth; and the mechanical seal is worthless when most needed—that is, in the absence of the water-seal.

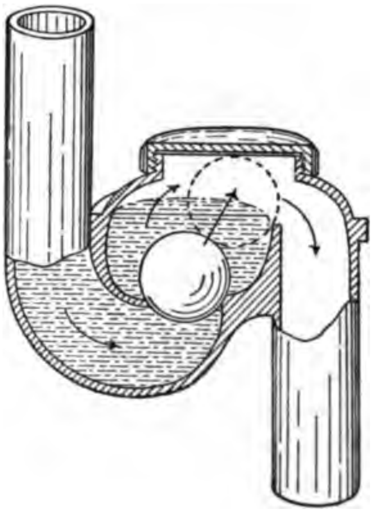


Fig. 208. Trap with Mechanical Seal Acting by Gravity.

Another mechanical seal trap, shown in Fig. 208, is the exact opposite of the previous example. The ball sinks by gravity, and effects a mechanical seal even when the water seal is absent. This trap is not so easily siphoned as a plain trap. It has a clean-out screw, and can be had with vent opening. Air from the sewer side acts against the clean-out cap through which access is had to the ball, and there are interior walls to become defective with little chance of discovery in practice.

A combined mechanical and water-seal trap is shown in Fig. 209, in which *D* is a hollow, flexible ball inclosing a metal ball D^1, thus giving a resilient seating surface that finds its place by gravity in water. The arrangement is proof against back-water, and the mechanical seal is positive without the aid of water. *A* represents the basin; *B*, the basin coupling; *C*, the valve seat; *F*, a glass cylinder body; and *GG*, a clamp with thumb-screw G^1, for clamping the cylinder body in place. This trap holds a large amount of water, and is not likely to become unsealed from lack of use, as part of the seal is protected by the ball, and should the water evaporate, the mechanical seal is still effective. There are no interior walls through which the trap could lose its seal without betraying the fact by leakage. Generally speaking, mechanical seals in fixture traps cannot be depended upon.

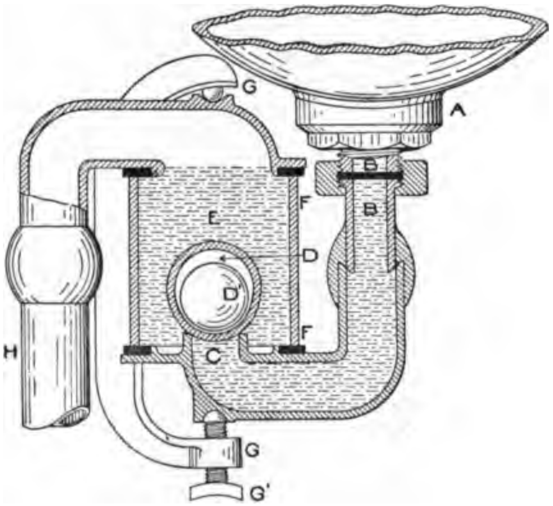


Fig. 209. Trap with Combined Water-Seal and Gravity-Acting Mechanical Seal.

Anti-siphoning traps are a blessing in instances where pipe ventilation is difficult. It would be better to have none of them, however, than to attempt to supplant pipe ventilation by their use to any great extent.

It would be impossible here to consider the whole list of traps individually in an adequate manner. What has been said should be enough to enable one by careful study to decide each case intelligently upon its merits. Many special traps are deserving of more favor than is generally shown them. It is the fear of seeming to indorse the horde of cheap competitive articles that causes many to ignore alike the good and bad. This fear is well grounded. The wolves will creep in if the door is opened at all.

Loss of Traps Seals. Traps may lose their seals in six ways—by *waving out*, by *capillary action*, by *leakage*, by *evaporation*, by *siphonage*, and—if the use of an unusual term be permissible—by *impellation*. The first, with its cause, has been described (see page 163). The last, like waving out, is caused by air-pressure, but on the house side instead of the sewer side of the trap. It occurs most frequently in intercepting traps where the fresh-air inlet has been connected too far from the trap, thus allowing heavy discharges of water and storm floods to compress the air between the fresh-air inlet and the trap. This action is of little consequence when so caused, as there is abundance of water to re-establish the seal. Its mention, however, suggests that a portion of the pipe is left unventilated by connecting the inlet too far from the trap. This error is usually made with good intention, because the foul-air outlet and fresh-air inlet are often made in the trap proper and are therefore too close together to pipe to the surface directly. There is a singular instance on record, of a trap having its seal broken by pressure on the house side—not from pressure of air in the pipe, but of that in the room into which the trap seal opened. This was a water-closet in a tight, unventilated compartment in a private house. Odors were often present which no one could account for. The job was new and first-class. The house was well built—too well. After many others had failed to diagnose the trouble, a plumber with some philosophy in his make-up examined the job. He stood in the hall, and slammed the closet-room door. It failed to latch, the room being so tight that the air-pressure kept it from seating on the rabbet of the frame. The door, of course, was instantly thrown partly open again by expansion of the air, and the plumber caught a glimpse of the water in the closet-bowl bobbing up and down. By repeating the experiment and measuring the depth of water between times, he discovered that, as suspected, the sudden closing of the door of the small, tight room was thrusting the water down in the bowl and causing enough to flow over into the soil pipe to break the seal. The trouble was remedied by cutting ½ inch off the door at the bottom.

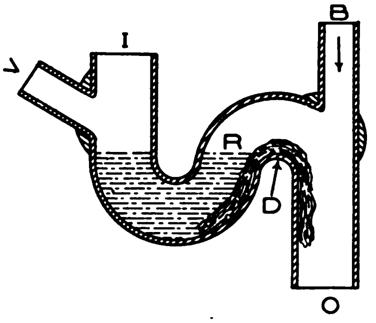


Fig. 210. Foreign Matter (Lint, Strings, etc.) Causing Capillary Loss of Trap Seal.

Evaporation has been described elsewhere. Leakage of seals has been mentioned in conjunction with types of fixture traps. Siphonage of traps is simple. The conditions necessary to start a common siphon being established in a waste pipe, the seal will be drawn out. The discharge of water from a fixture will siphon its trap (self-siphonage), if no provision against siphonage is made. The crown vent pipe, as described, breaks the siphon in a trap when its fixture is discharging, and prevents other fixtures from siphoning or waving out the seal. Capillary loss of seal occurs through hair, lint, and strings hanging over the weir of the trap. Dipping into the seal on one side, and ending in the pipe on the other, water will climb through or between such matter by capillary force, and will drip by gravity into the pipe. This is indicated by the tangled lines at *R*, Fig. 210, representing capillary material hanging over the outlet neck *D* of the trap. The trap indicated is for a lavatory with horn overflow bowl, *V* being the overflow connection, *I* the waste, *B* the crown vent, and *O* the outlet. Traps are sometimes locally vented at *V*.

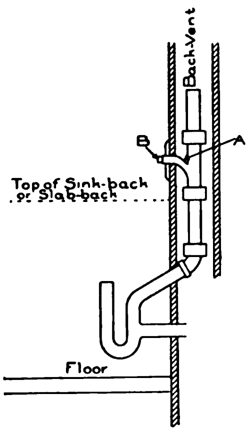


Fig. 211. Installation in which Provision is Made for Flushing and Cleaning Offset Vent Whenever Necessary.

Materials forming a porous coating on the inner walls of the trap through chemical action or otherwise, are now and then responsible for the loss of water-seal by action of a capillary nature. The shape of a trap may favor the accumulation of matter that will lead to capillary loss of seal. This is one reason why the plain, open-wall, cylindrical-bore traps are best. It is found that no matter how the trap is shaped, its cavity is, as a rule, not used except at the points which conform to the simplest, most direct course—as before said. Other shapes, then, present needless fouling surface and space for accumulation of matter that interferes with the proper service of the trap. Departure from the shape mentioned is necessary to secure an unvented trap that cannot be siphoned. Any trap that must necessarily be connected so as to put the air of the sewer side against the gasket of the clean-out cap, should not be used.

A difficulty common to venting the general run of plumbing fixtures, is presented by the fact that to crown-vent the trap prohibits sufficient immediate vertical rise of the crown vent to get above the fixture overflow-level, without making an offset in the vent, which, in case of stoppage of the waste, favors choking of the vent in the offset by matter floated into it as a consequence of the stoppage. A plan providing for flushing of the vent at will, is shown in Fig. 211, a sanitary tee branch being placed in the vent above the level of the sink or lavatory back, as shown at *A*, and closed by nickel-plated trap-screw cover *B* at the face of the finished wall. In this way, by removing cover *B*, a wire can be run through to the trap-screw clean-out, and the offset portion thus cleaned; and, if necessary, it can be flushed by injecting water at *B* with a hose or funnel.

TOOLS USED IN PLUMBING

Some of the tools used in executing pipe work will now be briefly described. Of the lead-pipe tools, Fig. 212 is a *drift plug* or *pin* used for removing accidental dents from, and rounding up, lead waste pipe after it has been coiled for shipment. It can be used only when the pipe is detached and comparatively straight. The plug is greased, and is forced through with a piece of gas pipe with a cap on the driving end. These plugs are made in various lengths, for all sizes of pipe, generally with a slight taper. Boxwood is best for the purpose, but dogwood and even softer woods are used. Three to five plugs constitute a set for one size pipe; the smallest being at least ¼ inch less than the diameter of the pipe, so that, when the plug of the exact diameter has worn so that it is too small, one of the smaller plugs for the next size larger, used to begin the removal of the dents, may be employed instead. After a pipe is in place, there is scarcely any easy way to remove a dent, except by soldering a strong piece of strap solder to the lowest place and gradually pulling the dent out, keeping it warm with the torch so that the lead will give easily.

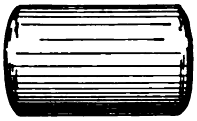


Fig. 212. Drift Plug or Pin.

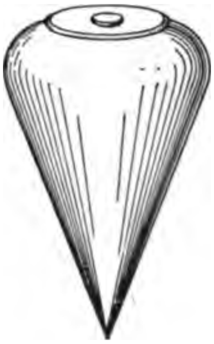


Fig. 213. Tampion or "Turn-Pin."

Fig. 213 is a *tampion*—generally called *turn-pin* by plumbers, because it is turned after each stroke of the hammer, so as to insure swelling the end of the pipe uniformly. The turning is necessary because the pins become somewhat oval while seasoning. The heart of the wood is seldom in the center of the pin, and the shrinkage therefore is not only quite unequal but varies as the center of the timber is eccentric to that of the pin. These pins are made of boxwood, with various tapers according to the work for which they are designed.

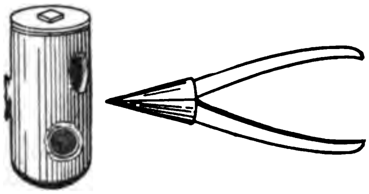


Fig. 214. Expanding Device for Enlarging Holes

Fig. 214 is an expanding device for enlarging holes in drum-traps and for aiding in preparing the receiving end of the pipe, as heretofore described for the turn-pin.

Fig. 215 is a *tap-borer*. It is made for boring the openings in traps and waste pipes, and for reaming out the ends of supply when preparing for wipe-joints. Its work is seldom true, and the turn-pin is used for finishing. The plumber's rasp plays an important part in the preparation for joints, especially in preparing the spigot end.

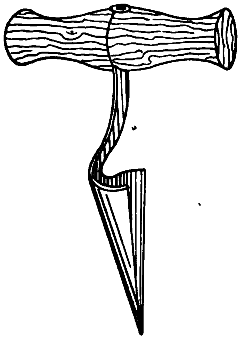


Fig. 215. Tap-Borer

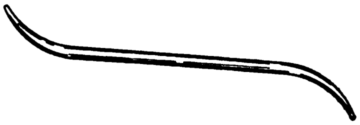


Fig. 216. Bending Iron

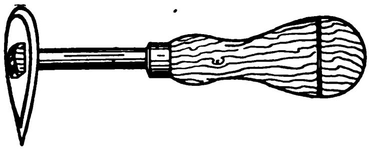


Fig. 217. Ordinary Shave-Hook

Fig. 216 is a *bending iron*, used for straightening the ends of pipe and enlarging holes made by the tap-borer, generally performing in a satisfactory way the work described in connection with Fig. 214.

Fig. 217 is a *shave-hook* of the type generally used on regular work. Lead tarnishes quickly; and in preparing joints, it is necessary to scrape clean the portion to which it is intended the solder shall adhere. The shave-hook is used for this purpose. To prevent reoxidation before use, joint cleanings must be immediately covered with tallow, lard, or sperm candle. The acid in sperm candle grease will cause solder to adhere where not intended, if one is not very careful.

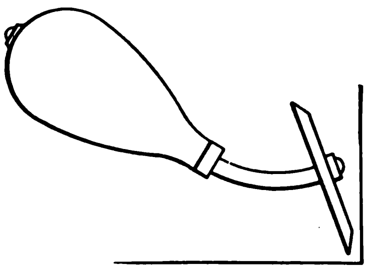


Fig. 218. Shave-Hook with Bent Shank, for Use in Corners and Other Inconvenient Places.

On new lead, *soiling* is necessary, regardless of the kind of flux used. The whole end of the pipe or other surface about a joint is soiled usually to a distance of four inches for wiping purposes, before making the cleaning. Plumber's soil consists of glue and lampblack, a little glue being dissolved in water, and lamp black added to make the mixture about the consistency of cream or thicker, the whole being boiled to incorporate the glue thoroughly. Soil should be laid on hot, with a brush. The surface to which it is applied must be free of grease and dirt, or it will not stick.

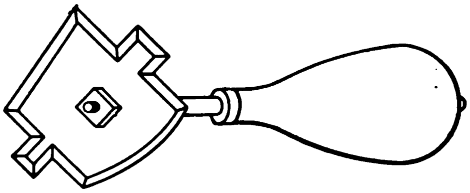


Fig. 219. Shave-Hook with Special Blade for Cleaning Seam Edges, etc.

Sheet lead is generally more or less greasy, no matter how clean and bright it looks, because tallow is used as a lubricator when rolling into sheets at the factory. New sheet lead should therefore be well rubbed with dry chalk, and dusted clean before soiling. Good soil should take a slight polish by rubbing with the hand after it is dried on the pipe. If it rubs off, there is not enough glue; if it cracks or peels or checks while drying, too much glue has been used.

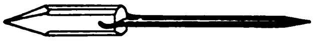


Fig. 220. Copper Bit or "Soldering Iron."

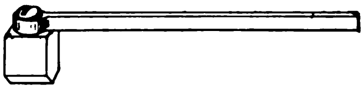


Fig. 221. Hatchet Iron,

Fig. 218 is a shave-hook with bent shank, convenient for cleaning in corners or other inconvenient places.

Fig. 225 is a special wrench for screwing up polished brass and nickel-plated pipe, the finish of which would be marred by a common wrench. Friction swivels, with link, for each size of pipe, are furnished with the wrench. In use, the gripping power of the swivel is proportional to the pull on the handle; and the grip necessary to turn the pipe, as it becomes tighter and tighter when screwed up, is increased regularly, without attention, by the natural increase of force on the handle. There are several kinds of wrenches used for the same purpose. The one shown will do its utmost on the shortest piece of pipe it is possible to apply a wrench to.

Fig. 226 is a three-wheel *pipe-cutter*, with a hinged block carrying one wheel in a way that makes it possible to cut many sizes of pipe with one tool. Three-wheel cutters are handy to cut pipe off when in close quarters, as the work can be done without rotating the tool around the pipe, a travel of the cutter handle through an arc of about 120 degrees being sufficient to cover the entire circumference of the pipe with the wheels. Three-wheel cutters raise the burr on the outside of the pipe, which in a great measure obviates the necessity of reaming the ends to get the full nominal bore area, as the scrimp stock from which the ordinary merchant's pipe of to-day is made gives an actual interior diameter considerably more than the nominal, and the stock burred inward with a three-wheel cutter is just about equal in its reduction of the bore to the difference between the actual and nominal inside diameters. On full-weight pipe of proper outsid diameter, the burr raised outside is very annoying to the fitter when new, close-fitting guides are in use, because it necessitates filing off the burr to some extent before the guide of the thread-cutting stock will slip over the end. On the other hand, with scrimp stock, where the outside diameter of the pipe is generally somewhat less than standard, the burr often constitutes the only portion of the thread that has a sharp top and bottom, which is necessary at some point in the thread to insure a tight joint. With worn dies and those of poor design, the outside burr acts in favor of starting the die without undue labor—a point of material advantage so far as labor is concerned when cutting threads on pipe of sizes smaller than those for which lead-screw die-stocks are furnished.

Other forms of pipe-cutters, with solid back and one wheel, or one wheel and two rollers, are made, the latter rolling the stock inward and making the burr so heavy that it should be reamed out. The wheel and roller cutters are used more than any other. They will cut true longer by retrograde motion.

In connection with cutting iron pipe, some reference should be made to *pipe-threading dies*, of which there are many makes, not all worthy of use. It is generally admitted that careless and incompetent handling and the general abuse to which pipe dies are subjected by the general run of pipe fitters, are largely responsible for the poor work turned out and the generally discouraging service obtained from such tools. But with mild-steel pipe, which does not run at all uniform in hardness, and which is more unsatisfactory in every way to work than is the genuine wrought-iron pipe, it is necessary to employ good and well-designed dies in order to avoid extra labor and expense and to produce creditable results in thread-cutting. The rake and form of the die must be suitable to the kind of material to be cut; and it is economy to purchase modern dies designed with this point in view, and then to give them the same treatment that would be gladly accorded fine machinery of any other type.

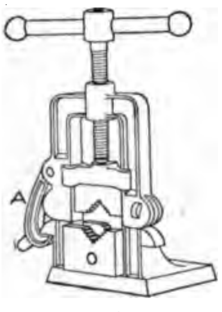


Fig. 227. Hinged Pipe-Vise.

Fig. 227 is a *hinged pipe-vise*. The upper jaw and frame are reversible so that the vise can be thrown open or closed to the right or left as required. The vise has a gravity pawl *A*, which drops into place automatically. A clutch at either side will engage the pawl when the vise is fastened to either the right or the left side of a post. A very desirable feature of the hinged vise is that pipe having fittings which will not pass through the frame at all can be quickly put in or taken out with no undue opening or closing of the screw, by simply lifting the pawl and swinging the vise back on the hinge.

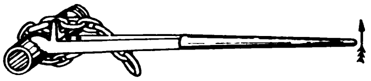


Fig. 228. Chain-Tongs.

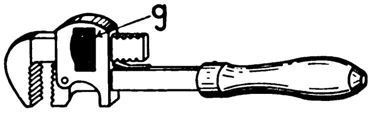


Fig. 229. Pipe Wrench for Small Work.

Fig. 228 represents a pair of old-fashioned chain-tongs, which may be used on any size of pipe the chain will reach around. There are other types, with double jaws, with chain hinged in center, which can be used either way, and which are more convenient.

Pipe wrenches are used for small sizes. Steel-handle wrenches are coming into use on large sizes. Fig. 229 shows a pipe wrench with wood handle, for small work. The jaw is opened or closed by rotating the knurled thumb-nut *g*.

Fig. 230 illustrates a plumber's *gasoline furnace*, adapted to heating solder pots and copper bolts. The gasoline supply for the blast passes through *AA*, and is provided with valve *H* and clean-out plug *I*. The lower end of the supply extends nearly to the bottom of the reservoir. The gasoline passes through coil *E*, which is partially filled with wire, usually a scrap of small wire cable, to prevent flame from running back into the reservoir, and issues from a single small hole at *F*, which is turned so that the flame will impinge on the coil. Air-pressure on top of the gasoline in the reservoir is necessary to make a blast. The air-cock is shown at *G*. For ordinary purposes, sufficient pressure can be obtained by blowing air in the hose at *C* with the lungs; but for a strong blast, a bulb containing check-valves, shown at *D*, is used to increase the pressure. The filling screw is at *B*.

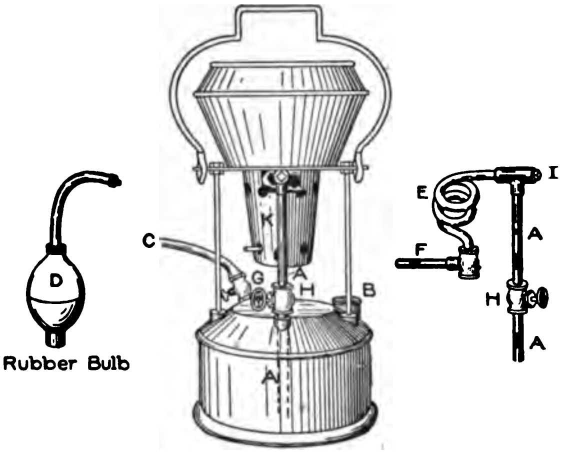


Fig. 230. Plumber's Gasoline Furnace.

To light the furnace, valve *H* is opened and some of the gasoline allowed to play on the coil, from which it falls back into the bottom of cup *K*. When about two tablespoonfuls have reached the cup, close *H*, and light the gasoline through one of the holes in *K*. When it has burned out, the coil will be hot enough to vaporize the gasoline as it passes through it; and a gas instead of a liquid then issues from *F* in the form of a blast, which increases in intensity as *E* becomes hotter. Any tendency to produce more gas than necessary merely increases the pressure and the force of the blast. The strength of the blast can be regulated by valve *H.* As the air is forced into the reservoir above the gasoline, one pumping keeps the furnace in working order, until the lowering of the gasoline level has provided so much room that the pressure of the expanded air is not sufficient to maintain the blast. Then it becomes necessary to pump in more air, or to replenish the gasoline and again establish the pressure over it as described.

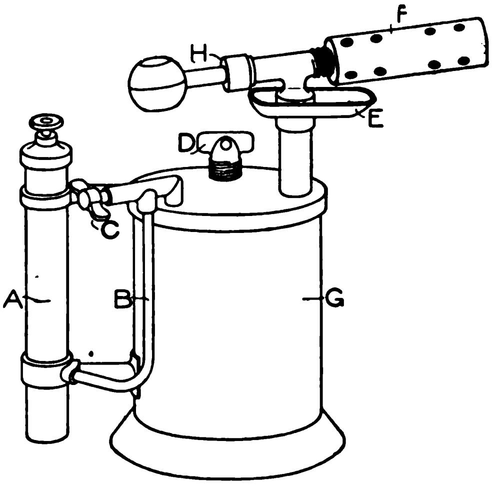


Fig. 231. Plumber's Blast Torch.

Fig. 231 is a *blast torch* used by plumbers for warming large joints, melting off old joints, heating soil-pipe hubs, thawing frozen water-pipe, etc. The principle of operation is the same as that of the furnace. *A* is a hand-pump for establishing the air-pressure; *B*, the air-pipe; and C, the air-cock connecting the pump to the top of the reservoir *G.* *D* is the filling screw, and *H* the supply valve to burner. The gas issues from a single orifice within the hood *F.* *E* is a gasoline cup used to heat the burner in order to start the blast, and corresponds to cup *K* of the furnace.

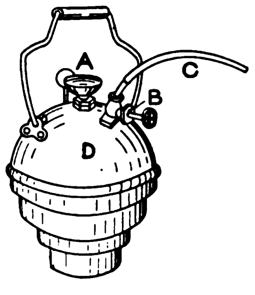


Fig. 232. Thawing Steamer.

The *thawing steamer,* Fig. 232, is made of heavy copper and adapted to fit the bowl of a plumber's blast furnace. *A* is the safety-valve, *D* the reservoir, and B the valve connecting with the steam space. For use, the reservoir is filled about three-quarters full of water, and heated to steaming point. The steam is conveyed through a hose *C*, and injected into the end of the frozen pipe. As the ice melts and the water flows out, the hose is pushed further and further into the pipe, until the ice is all melted out of the frozen portion. This is an admirable way to thaw water-pipe frozen underground, within partition walls, and in other inaccessible places.

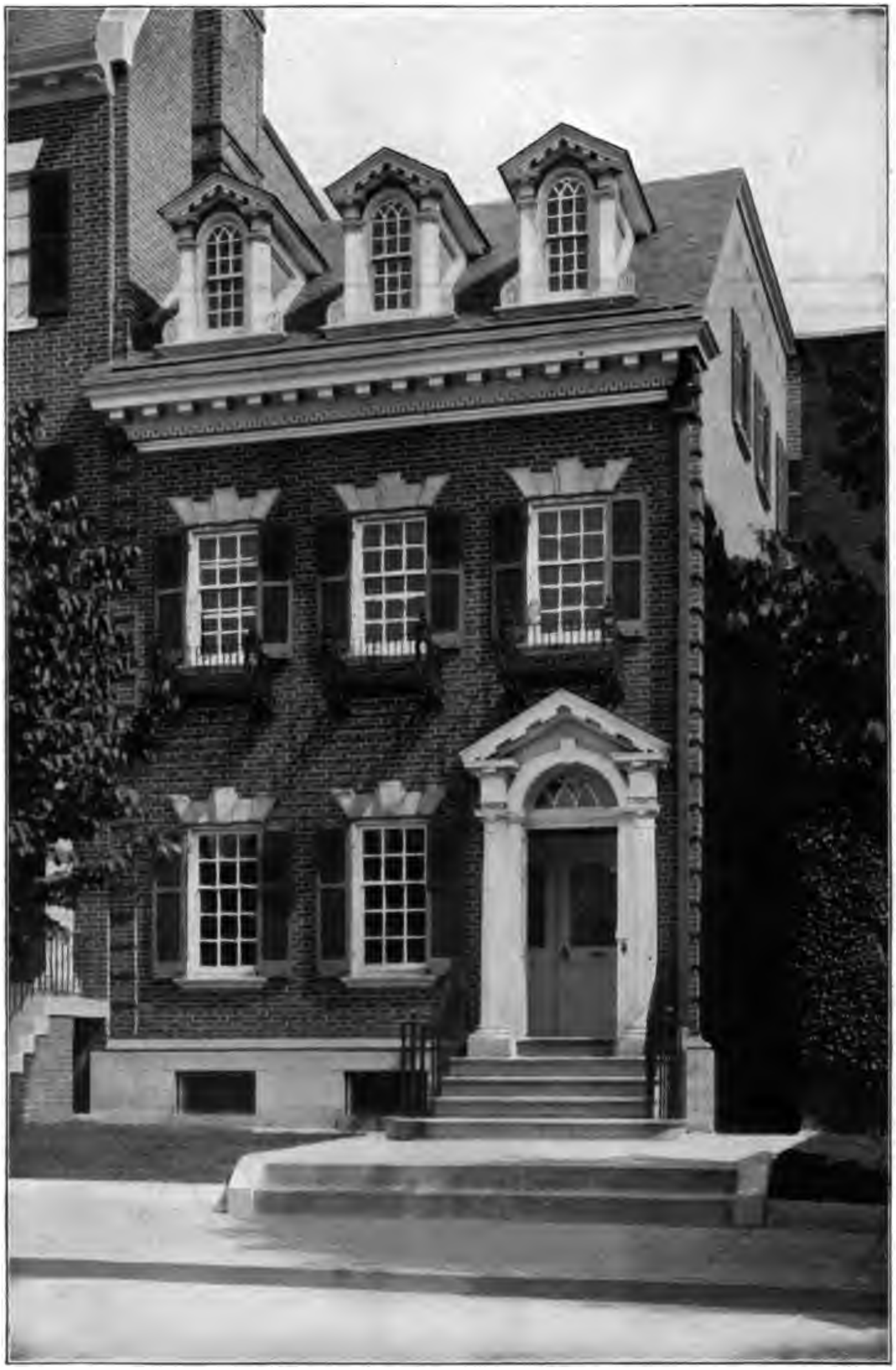
There are numerous other tools used by the trade not only peculiar to the plumber's needs, but used also in common by workmen in other lines. All the data necessary concerning them can be had by reference to catalogues.

METHOD OF WIPING JOINTS

Watching somebody wipe joints, a clear description of how it is done, a thorough knowledge of the theoretical process, and acquaintance with the traits and qualities of the materials used, are essential; but practice in the art of wiping joints has more to do with making one proficient than has mere practice to do with proficiency in any other line of work. A Hottentot would succeed about as well in engrossing a set of resolutions, upon his first introduction to English and a pen and ink, as the most skilful person in other lines would in the work of wiping a joint at the first attempt. One may give the closest attention to the manual operations of making a thousand joints when the cloth and ladle are in the hands of someone else, and yet fail to remember the how and wherefore of a hundred movements absolutely necessary to success. Some general remarks are therefore all that will be of real benefit to any one previous to practice.

The same general result must be attained under a great variety of conditions, regardless of position or size or character of the pipe. The temperature and composition of the solder; the temperature of the weather; the kind, size, and position of the joint, etc., must be reckoned with in every instance, and each modifies the proceeding more or less at some stage.

Before commencing to wipe a joint, one should be positive that it is firmly set; that the cleaning is well done and of proper length; that the junction of the ends is well made, so that solder will not run through into the pipe; that the surrounding edges are well soiled, pasted, or otherwise protected, so that the solder will not adhere except at the cleaning; that the pipe is dry inside and outside; that no undue current of air is passing through it; that there is enough solder in the



HOUSE IN WASHINGTON, D. C.
Wood, Donn & Deming, Architects, Washington, D. C.
Doric Colonial Front.

pot to get up the heat and do the work; that the solder is hot enough; and that the cloth is in good condition.

To prepare for a joint, square the end of the pipe; see that the bore is true; rasp the spigot end evenly down to the bore, a little more obtuse to the outside surface than it is intended to make the boring or opening of the receiving end to that of the interior surface. Always rasp against the end of the pipe, so that no burr is made on the inside and so that none of the raspings get into the pipe. If the receiving end is to be opened with a turn-pin, the rasping on the spigot end should be made according to the taper of the turn pin, and the bell end should be rasped down only partially, leaving stock enough to stretch when the end is expanded with the turn-pin. If the receiving end is to be opened with a tap-borer, then the spigot end must be rasped down in accordance with the angle of its boring. A coarse rasp will do to rough the work with; but one of fine teeth should be used to do the finishing so that the shave-hook will remove its marks. When the ends are thus prepared, soil them back three or four inches; and when dry, clean with a shave-hook, cutting rather deeply at the beginning of the cleaning so that there will be a slight thickness of solder at the edges of the joint; otherwise it would be impossible to wipe the edges clean and perfect, because the feather edge will chill too quickly. Before setting the joint, the tip edge of the spigot end and the bottom of the receiving end should be soiled, so that the two soiled parts will come together when the pipe is in place. This keeps solder from sweating through into the pipe.

The length of cleanings does not increase with the diameter of the pipe. The idea is to have the solder contact surface in proportion to the strength or purpose of the pipe. A round joint on ⅝-inch pipe and one on 8-inch soil pipe should be about the same length—2 to 2¼ inches. On 4-inch soil pipe, the average width of a joint is about 1½ inches. When the pipes to be joined are of different metals, it is best to increase the length of the joint somewhat, or extend the tinning. For instance, on copper pipe—especially for distillery use—some kind of galvanic or corrosive action takes place which destroys the union between the solder and the metal of the pipe. It is therefore usual, on distillery work, to tin across the end of the pipe and back on the interior, in addition to the regular joint surface outside, making the tinning continuous, as its length and continuity seem to determine the period of time the joint will last.

Difference in the ratios of expansion, causing a shearing action, appears to have much to do with the life of joints when lead and brass, lead and copper, or lead and iron are joined together by wiping. This is noticed more on water-back connections than elsewhere in the regular line of plumbing. When lead is joined to lead, the difference in the coefficients of expansion for the mass of solder and the metal of the pipe with which it is in contact, is so slight that little trouble is experienced in this way. The contour of the joint may be decided by allowing the thickness of solder at the middle to equal one and a-half times the thickness of the wall of the pipe. This holds good for supply pipe where the solder used is 40 to 45 per cent good tin and 55 to 60 per cent pure lead. On thin wall soil and waste pipe, or where coarser solder is used, twice the thickness of the wall is better The solder forming the joint must be patted up compactly before wiping.

The beginner should keep the solder hot, leaving the pot in the furnace while practicing, so that he can put back and re-melt the cold batches from time to time, and continue to pour and re-wipe without loss of time. He can do no better than to try to imitate the motions of those who know how, whether he yet fully comprehends the reasons or not. Practice will soon teach him a few points which words cannot explain to the inexperienced. Lead and tin, not being of the same specific gravity, stratify more or less when melted, the tin rising to the top. For this reason, the molten mass should be skimmed and well stirred before dipping out any to wipe with. Never stir solder until ready to use it. Let the novice take the cloth in the left hand, holding it forward so as to cover the tips of the fingers, and take a ladle of solder in the right. Hold the cloth under the cleaning and drop the solder drop by drop upon the cleaning at different points, gauging the number, rapidity, and size of drops according to the heat of the solder. A single drop of solder too hot, may melt a hole through a thin wall pipe after it is pretty well warmed up. Keep the ladle moving so that the drops will fall in different places. When some solder gathers on the cloth, put it up on top again, and drop solder on it. When more runs down on the cloth, hold it against the bottom of the pipe to warm the bottom; and continue to drop solder from the ladle, more particularly now about the edges and even extending the pouring two inches or so out on the soiled part of the pipe on each edge, which will help to warm the pipe and provide heat in the pipe adjoining the edges of the joint to help keep the joint hot enough to wipe the edges clean before they chill.

Do little rubbing or passing on the edges. Let the solder stack up; dig some out of the top of the mass with the ladle to temper fresh solder from the pot, so that pouring a liberal stream instead of drops will do no damage. When the pipe has absorbed enough heat to allow the cold masses at the edges to be lifted easily, pass the mass around a little so as to tin the cleaning. Keep plenty of solder on the cleaning, and let the edges take care of themselves until the last.

When there is a good mass of solder on the cleaning, and the edges are thick and mushy, do extra pouring on the edges to get them thoroughly hot, and then place the solder on the cloth upon the pipe. If it is hot enough, the solder will tend to run off at either side again; but it must be caught and pushed up. Then, with the aid of the thumb or an extra cloth in the right hand, push the solder around keeping plenty at the bottom, and get it patted up compactly into an egg shape with thick edges extending over on the soiled part, as quickly as possible. It may be necessary to pass or rotate the mass so as to get the cooler solder on the top to prevent it from dripping from the bottom. Experience will teach one how to mix the overheated portion with the balance so as to have the solder approximately at uniform temperature at all points by the time the joint is patted up.

The joint roughly shaped as described would hold water quite as well as after it is finished; but the appearance is bad.

Clean the edges first by pulling the cloth around, bearing down on one edge at a time. Then spread the middle and index fingers so as to let the cloth sag between them, and finish the joint by pulling the cloth around while bearing on both edges at the same time, keeping hold of the cloth by pinching it to the palm of the hand with the thumb. Beginners usually draw the cloth lengthwise of the joint to cut off the surplus carried around on the cloth by the finishing wipe; but an experienced person can finish the wiping while the solder is yet hot enough to sweat-in the cloth marks of the final wipe.

If the joint is wiped hot enough, and the heat evenly distributed, the tin spots on the surface when the joint is cold will be evenly distributed over the surface. If the pipe is hot enough, and the mass of solder too cold at any point, the friction of the cloth will cause the whole mass to rotate on the pipe. If too hot on the bottom, it will bleed the mass by dripping at the bottom. If too cold on top or at any other point, a very poor shape will result—if, indeed, one is able to wipe the joint at all. If the solder is fine, and a single wipe is made after the solder has fallen below the proper temperature, the surface will be covered with briar-like projections. If the solder contains any zinc, it will be brittle and work like cornmeal dough, and drip at the bottom when finished, if finished at all. All brass goods contain more or less zinc in alloy with copper, and it is best never to tin brass in wiping solder, as the zinc will melt out and ruin the solder.

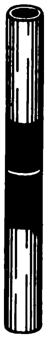


Fig. 233. Butt Sweat Joint.

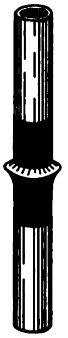


Fig. 234. Blow Joint.

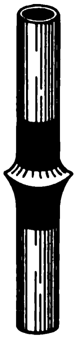


Fig. 235. Copper-Bit Joint.

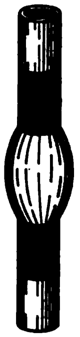


Fig. 236. Round Wiped Joint on Small Pipe.

Many plumbers use two cloths when wiping. To become expert with the cloth, it is better to wipe all kinds of joints with one cloth only, until thoroughly proficient; then, if a second cloth is found to be of real service in some instances, use it.

A beginner may take every advantage to aid him—such as choking a pipe to keep cold air from passing through, heating brass or copper edges with a torch before wiping, placing a live charcoal on a piece of screen wire within the pipe to aid in heating up, wiping large joints in sections and meeting the edges by chalking the finished part as described in connection with tank seams, etc.—but he should never be guilty of making extra joints in order to shirk a difficult position. The quickest plan to master this branch of work, is to make joints in whatever position they happen to be required, instead of trying to arrange an easy way.

Wiped joints should be made wherever practicable; but there are several other styles of joints equally serviceable for certain locations. Fig. 233 is a *butt sweat-joint* made by squaring the ends, tinning one end, and sweating the other to it by heating with a torch. It is the weakest joint made, but will at the outset stand any strain or internal pressure that the pipe itself will stand.

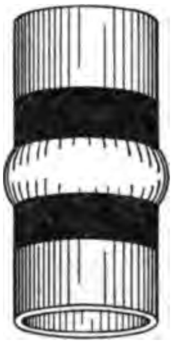


Fig. 237. Round Joint on Large Pipe.

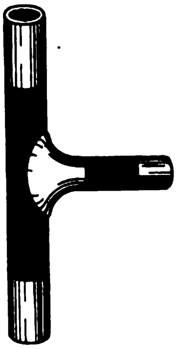


Fig. 238. Branch Joint with Concave Neck.

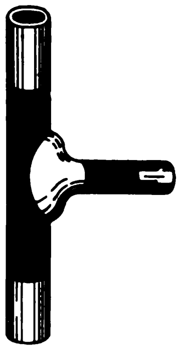


Fig. 239. Branch Joint with Swell Neck.

Fig. 234 is a *blow joint.* The only difference between it and the *copper-bit joint* shown in Fig. 235, is that the solder is floated by aid of the torch, and it is not so heavy as Fig. 235. The copper-bit joint is made with the soldering iron, the solder being melted and floated a little at a time until the joint is completed.

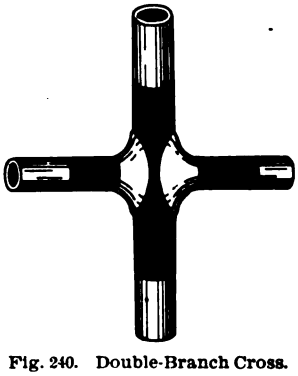


Fig. 240. Double-Branch Cross.

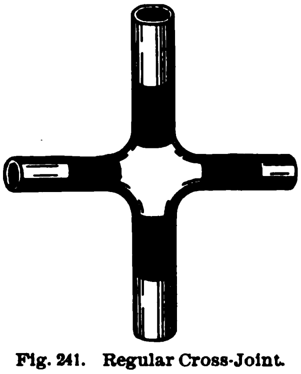


Fig. 241. Regular Cross-Joint.

Fig. 236 is a *round wiped joint* on ⅝-inch supply pipe. For comparison a round joint on 5-inch soil-pipe is shown in Fig. 237.

Fig. 238 is a supply-pipe *branch joint with concave neck.*

Fig. 239 is a supply-pipe *branch with swell neck,* much more difficult to wipe than the style shown in Fig. 238.

Fig. 240 is a *double-branch cross.* This style of cross looks well, and is very easy to wipe, because one branch may be wiped at a time by protecting the first with chalk or paste.

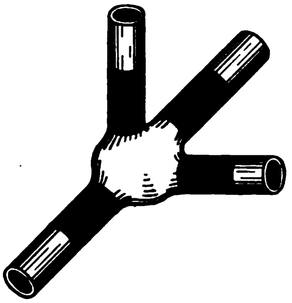


Fig. 242. Angle Cross.

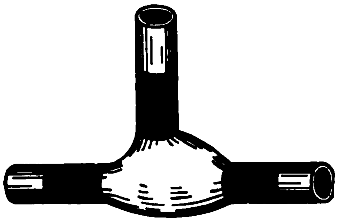


Fig. 243. Combination Branch and Round Joint.

Fig. 241 is a *regular cross-joint,* more difficult than the double branch because there are four edges to take care of at one heat.

Fig. 242 is an *angle cross,* more difficult if anything than the wiping of Fig. 241.

Fig. 243 is a *combination branch and round joint,* sometimes made where it is most convenient to have a branch joint come at a point where two ends of the supply line must also be joined.

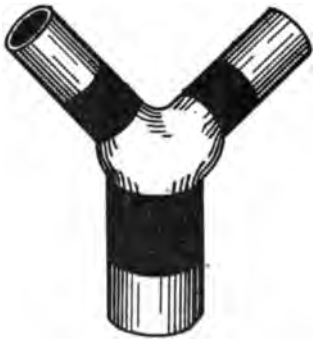


Fig. 244. Y-Joint, Used Generally on Telephone Branch Cables.

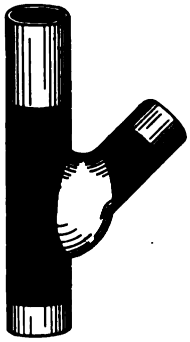


Fig. 245. Y-Joint on Lead Waste-Pipe.

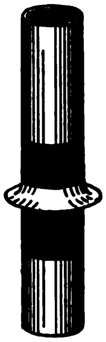


Fig. 246. Common Flange Joint.

Fig. 244 is a *Y-joint.* This form of Y is rarely wiped except for branch cables on telephone work. Many so-called Y-joints are made at a Y-angle on lead waste-pipe work, as shown in Fig. 245. As a general rule, none of these combination joints are made frequently enough of late years to keep a plumber in good practice. A common wiped *flange joint* is shown in Fig. 246.

An inclined joint can be set easily with two pairs of old dividers and two blocks to hold the pipe away from the wall. The table to catch what falls, should be a little toward the low side rather than centered under the cleaning. To wipe a joint in this position, pour well out on the soil, and let it stand without attempting tq do much with the cloth. Temper the solder from the pot by digging out of the stack on the joint, and pour liberally. After the cold edges get melting hot next the cleaning, lift them into the pot. Then begin to pass the solder around with the cloth. Keep a good mass on the pipe. Pat up when hot enough, and cut the high edge clean first; then the top of the low edge. Then make some trial wipes, without pulling off any solder, to see if the joint is filled out to the proper contour all around. If not, use the surplus to fill the low places; then wipe down to the desired shape quickly. If the joint takes on any symptoms looking as if it had been stung by a bee on the low end at the bottom, cool it quickly with water.

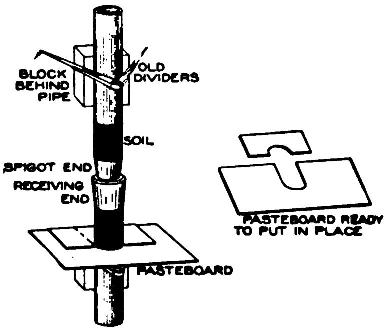
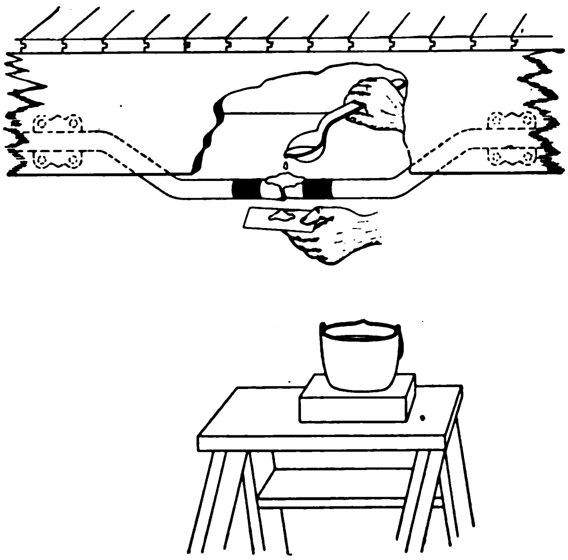


Fig. 247. Upright Cleaning Ready to Wipe.

To protect the wall on a flange joint over new wood wainscoting, such as is often made on sink wastes and vents, a large piece of pasteboard should be fitted over the pipe before the end is flanged. A blind flange joint requires a lead flange to be tacked to the wall over the pipe to support the joint. It is best to fit a lead flange the size of the joint in all cases, as less stretching of the pipe end is then necessary where the flange is also a union of two pieces of pipe. After the joint is finished, the pasteboard can be carefully cut around it and removed, leaving the wall clean. If the flange is to be made over marble, the pasteboard keeps the heat from running away from the edges, and there is less danger of cracking the marble by heat.

An *upright cleaning* is shown ready to wipe in Fig. 247. Plain upright joints are so easy, and occur so frequently, that the art of wiping them is soon mastered. The receiving end should be below and should be opened with the turn-pin and rasped off to suit. Its lower, inner edge and the tip of the spigot should be soiled. The ends should fit well, and the open part taper a little more than the spigot. The bulge helps to keep the solder up; and the cup, if well cleaned, will make a good joint alone. When wiping, either spit the solder on with a stick or pour on the cloth and drift it against the cleaning. Keep the mass up. Endeavor to pour solder on solder instead of on the cleaning. Leave the bottom edge alone until the cold fringe loosens of its own accord. When hot, form up roughly, high, and cut the top edge off clean first; then drag up the settling bottom edge, and fill out the low places; then wipe to finish, bearing the hardest on the upper edge of the cloth. The table can be made of two pieces of pasteboard as shown. Set it low enough to let the cloth and hand clear what drops when wiping. If cold solder surrounds the pipe when finished, melt it apart with the copper.



No. 248. Wiping an Overhead Joint

The *overhead joint*, shown in Fig. 248, is wiped in the same way as though it were on the floor. The position is a trying one, and the cloth and ladle are kept in place at a great disadvantage. A stiff cloth is best to get the heat with; while a second, more flexible and previously warmed, can be used in conjunction, to do the shaping and wiping. Some heat previously applied with the torch to the edges, will shorten the time of getting the heat, and save the wrists and fingers from cramp and excessive tiring. Some provision for straightening the line is necessary, if a straight shoot is too high to wipe. Sometimes the surplus pipe is *snaked* into one horizontal plane with proper incline so that the pipe will drain, and is supported by a shelf.

THE MAKING OF CALKED JOINTS

In working cast-iron soil-pipe, frequent *cutting*, as it is termed, is necessary. To do this, all that is required is a hammer, and a cold chisel not too sharp. Make a line around the pipe as a guide, to insure making the piece the same length at all points. Then begin with hammer and chisel, pointing the chisel straight toward the center of the pipe and striking it quick, moderate blows, moving the chisel a little forward on the line after each blow, so as to make a continuous dent all around the pipe. Continue working in the dent until the pipe falls apart. The separating of soil pipe in this way is not a cutting process at all; it is simply packing the iron down in a line until the fiber of the iron is disturbed entirely through the wall, or at least sufficiently to wedge the pipe apart. Where the chisel strikes, the force tends to make the pipe longer, and the strain thus produced wedges it asunder.

Tools Used in Making Calked Joints. Fig. 249 is a *yarning tool*, the blade being long and thin in order to reach the bottom of the hub. The offset in the handle is to keep the hand out of the way of the pipe when using it. The *calking tool* is of the same pattern, with shorter blade and heavier. For calking and yarning joints standing close together or in a corner, special forms are needed. The *corner* tools, as they are called, are offset twice—once to keep the hand free of the pipe,

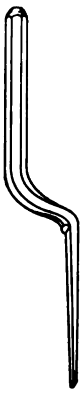


Fig. 249. Yarning Tool.

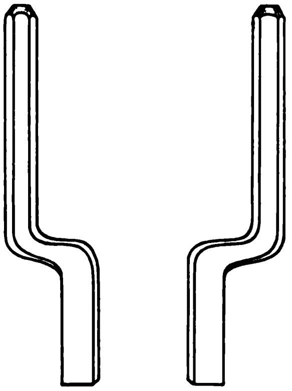


Fig. 250. Fig. 251.
Right and Left "Corner" Tools for Calking and Yarning.

and once edgewise, throwing the blade out of alignment both ways. The offset part next the blade is curved to the arc of the largest pipe it is to be used on, so that the blade will reach down in the hub vertically at the back of the joint, while the handle stands free in the open space for manipulation with the hand or hammer. These tools are necessarily made right and left, as shown in Figs. 250 and 251.

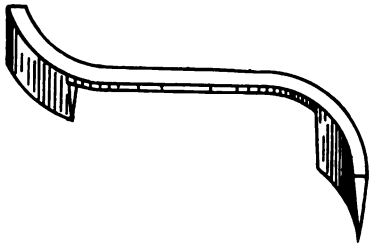


Fig. 252. Right and Left Calking Tool.

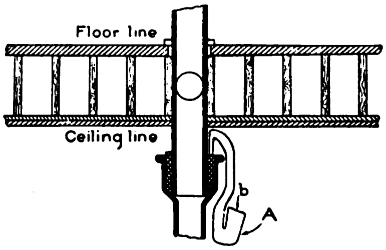


Fig. 253. Use of Special Tool in Calking Joint near Ceiling.

Another form of right and left calking tool is shown in Fig. 252, for use in finishing the joint as described in connection with Fig. 190.

Joints near the ceiling or in other positions, sometimes have to be made in places where regular tools cannot be used. The application of a special tool for the purpose is shown in Fig. 253, *b* being the hammer face, which is in position to use the hammer on quite conveniently. The hammer end *A* is made extra heavy, not only to prevent losing the force of the blow by vibration, but to give it weight in making effective jerking blows with the hand when pulling the yarn in.

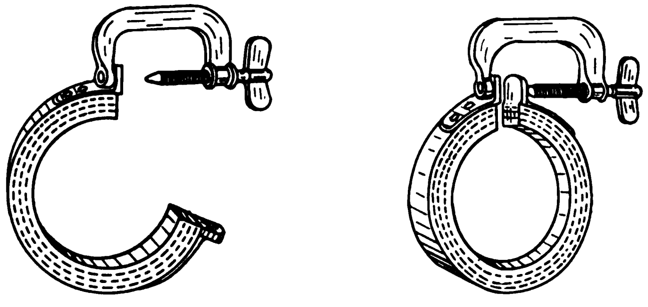


Fig. 254. Asbestos Joint-Runner, Open and Closed.

Fig. 254 illustrates a *joint-runner* made of square asbestos rope, with hinged clamp and thumb-screw attached for holding it in place.

There are other forms made that are just as good. These are used in running horizontal and oblique joints on cast-iron soil-pipe work. A fire-clay roll, formed about a strong cord by hand and used just damp and soft enough to bend and pinch in place, answers the purpose very well, though the weight of the lead, aided by steam bubbles formed from the water in the clay, sometimes blows them loose and imposes on the plumber the hard task of getting ready to re-run the joint, to say nothing of the time lost.

TESTING PLUMBING

Peppermint and ether are now but little used to test the tightness of soil and waste pipe. Better methods prevail. When the roughing-in work is finished, a *water test* is applied. The openings for fixtures and the outlet being closed, the whole system is filled with water, and no further progress permitted until it is water-tight. To avoid extra work in taking out defective pipe and fittings, cracked hubs, etc., it is best to fill the pipe as installed. Defects of material and workmanship are then brought to light at a time when they can be remedied at the least expense.

After the fixtures are set and connections made, a *smoke test* is applied to the completed job before it is passed for actual service. Devices for filling the pipe with smoke by burning rags or waste, are a part of every shop's equipment where city ordinances prescribe this kind of test. These are called *smoke machines*, and are moderate in cost and simple in operation. The smoke test is made under one to two inches' water-pressure, the pressure being shown by a water-gauge on the machine.

PLUMBING LAWS AND ORDINANCES

The municipal control of plumbing in the United States dates back only about twenty-five years, although some simple regulations were in effect in Lowell, Mass., and Providence, R. I., as early as 1878. The earliest codes with any claims to completeness took effect in 1881. The first such rules were made under the authority of general statutory provisions which conferred power on local governments to legislate on sanitary affairs. It soon became evident, however, that State legislation was necessary in order to give proper uniformity to the method of control; and general plumbing laws have now been enacted in more than twenty States.

The application of the police power in the State—which may be broadly defined as "The power of promoting the public welfare by restraining and regulating the use of liberty and property"—was at first questioned when used in this connection. Owing, however, to the advances in public opinion regarding these questions of general welfare, it has been settled by numerous decisions that the regulation of plumbing construction by competent persons and in accordance with well-defined laws of design is a proper function of the Commonwealth. A recent authority has said: "The legislation on this subject has been the result of evolution, and conditions that were at one time tolerated are now recognized, with the growth of knowledge and the advance in sanitary science, as dangerous to life and health."

The scope of plumbing laws varies in the different States. They usually provide in general terms for the establishment of a Plumbing Board in each of the larger cities. Such a board generally includes at least one master and one journeyman plumber, together with some member of the Board of Health, or other city official, whose duties bring him closely in touch with plumbing construction. This board has authority to examine candidates for licenses as master plumbers and for journeymen's certificates, and to determine their competency to conduct the business or to work at the trade. If an applicant is not found competent, he is forbidden to do plumbing work. Either the board as above constituted, or the Board of Health, is charged with the duty of regulating plumbing design; and in most cities, ordinances have been framed with this end in view. The method by which plumbing shall be controlled is sometimes defined by the state law, and is in other cases determined by provisions of the city charter.

The extent to which regulations and ordinances prescribe the types of construction, varies greatly. In the smaller cities, a simple regulation comprising a few paragraphs is all that is found necessary. In the larger cities, long and complicated ordinances, with many provisions describing in great detail the materials that may be used, the method of venting, etc., have been framed. The great advances in plumbing design and in types of fixtures available create a necessity for some adaptation of plumbing rules to changed conditions.

The jurisdiction under which the control of plumbing inspection should be placed—whether with the Department of Health or with the Building Bureau—has been a subject of some controversy. The enforcement of the earlier plumbing rules was entrusted to the sanitary authorities; and the supervision of plumbing is, in many of the larger cities, still in the hands of the Health Department. There has been, however, in the last few years, in connection with the more detailed study of features of plumbing design, a well-defined feeling that the questions of greatest importance fall within the province of the Sanitary Engineer, and may be logically treated by that department which has control of other details of building construction. In New York and Boston, as well as in some smaller cities, jurisdiction over the Plumbing Bureau is placed with the Department of Buildings.

Although the extension of plumbing supervision to those cities where it has not previously been in existence has been rapid, there still remain a number of large cities and many smaller ones which have neither regulations governing plumbing nor inspectors to supervise plumbing construction; and in many States no movement has yet been made to frame general laws upon this subject.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

HEATING AND VENTILATION

PART I

---

1. What advantage does indirect steam heating have over direct heating? What advantages over furnace heating?

2. What are the causes of heat loss from a building?

3. Why is hot water especially adapted to the warming of dwellings?

4. What proportion of carbonic acid gas is found in outdoor air under ordinary conditions?

5. A room in the N. E. corner of a building of fairly good construction is 18 feet square and 10 feet high; there are 5 single windows, each 3 by 10 feet in size. The walls are of brick 12 inches in thickness. With an inside temperature of 70 degrees, what will be the heat loss per hour in zero weather?

6. State four important points to be noted in the care of a furnace.

7. A grammar school building, constructed in the most thorough manner, has 4 rooms, one in each corner, each being 30 ft. by 30 ft. and 14 ft. high, and seating 50 pupils. The walls are of wooden construction and the windows make up $\frac{1}{3}$ the total exposed surface. The basement and attic are warm. How many pounds of coal will be required per hour for both heating and ventilation in zero weather, if 8,000 B. T. U. are utilized from each pound of coal?

8. What two distinct types of furnaces are used? What are the distinguishing features?

9. What is meant by the efficiency of a furnace? What efficiencies are obtained in ordinary practice?

REVIEW QUESTIONS

ON THE SUBJECT OF

HEATING AND VENTILATION

PART II

1. How would you obtain the sizes of the cold-air and warm-air pipes connecting with indirect heaters in dwelling-house work?

2. What is an aspirating coil, and what is its use?

3. What efficiencies may be allowed for indirect heaters in schoolhouse work? How would you compute the size of an indirect heater for a room in a dwelling-house?

4. How is the size of a direct-indirect radiator computed?

5. A schoolroom on the third floor is to be supplied with 2,400 cubic feet of air per minute. What should be the area of the warm-air supply flue?

6. What is the chief objection to a mixing damper, and how may this be overcome?

7. How many square feet of indirect radiation will be required to warm and ventilate a schoolroom when it is 10 degrees below zero, if the heat loss through walls and windows is 42,000 B. T. U., and the air-supply 120,000 cubic feet per hour?

8. What is the difference in construction between a steam radiator and one designed for hot water? Can the steam radiator be used for hot water? State reasons for answer.

9. How may the piping in a hot-water system be arranged so that no air-valves will be required on the radiators?

10. What efficiency is commonly obtained from a direct hot-water radiator? How is this computed?

11. How should the pipes be graded in making the connections with indirect hot-water heaters? Where should the air-valve be placed?

12. Describe briefly one form of grease extractor.

REVIEW QUESTIONS

ON THE SUBJECT OF

STEAM AND HOT-WATER FITTING

1. What points should be borne in mind when selecting a heating boiler for a given service?

2. Explain by an example how to check the catalogue rating of a boiler.

3. Point out the difference between (a) direct, (b) direct-indirect, and (c) indirect radiation.

4. State the advantages of each type.

5. What advantages do overhead coils possess over other classes of direct radiation?

6. (a) With overhead coil heating, how should the coils be placed with reference to walls and floor to secure the best results? (b) Why?

7. In what two ways is heat given off by a radiator?

8. What advantages has a wet return system over one with dry returns?

9. (a) In what classes of buildings, as a rule, may the overhead feed system be used and why? (b) What advantages are possessed over the up-feed system?

10. When should a two-pipe system be used in preference to a one-pipe?

11. Explain the action of a siphon trap in balancing a low-pressure steam heating system.

12. When is it advisable to establish an artificial water line?

13. What appliances are necessary in connection with exhaust steam heating that are not used with ordinary low-pressure heating?

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING

PART I

1. Under what conditions is a spring of water available for house supply?

2. What methods are adopted of supplementing municipal service in case of insufficient pressure?

3. What are the essential requirements of a good laundry tray?

4. What do you consider the poorest types of waterclosets?

5. What are the general methods of supplying buildings with water?

6. How far should the bottom of a cistern be below the cylinder of an ordinary house suction pump?

7. How is *siphonic eduction* effected in the case of range closets? Illustrate by diagram.

8. Describe the part played by lead in modern plumbing.

9. What is a *pneumatic siphon* closet? Give diagram.

10. How can an open-trough range closet be satisfactorily ventilated?

11. How can supply to tanks be automatically regulated?

12. When is a hydraulic ram available for house supply?

13. Describe the various kinds of bathtub supply and waste fittings.

14. What are the advantages or disadvantages of the *combined hopper and trap* and the *wash-out* types of closets? Illustrate by freehand sketches.

15. Classify bathtubs (1) according to material; (2) according to shape. Illustrate the shapes by freehand sketches. Discuss the relative merits of the different classes of bathtubs.

16. Describe the different types of lavatories.

REVIEW QUESTIONS

ON THE SUBJECT OF

PLUMBING

PART II

---

1. Describe the essential features of a stove or range connection of a reservoir.

2. Explain the principle of the Bunsen burner. What application does it have in connection with lighting by gas?

3. How many square feet of heating surface will be needed in a submerged brass coil filled with steam at 7 pounds pressure, to raise the temperature of 125 gallons of water per hour from 40 degrees to 200 degrees?

4. What is the cause of rumbling in a reservoir?

5. What is the object of the siphon hole in the delivery pipe in a reservoir?

6. Describe the different classes of filters.

7. Draw a diagram showing connections of hot-water reservoir (1) to a single water-back; (2) to two water-backs on different floors.

8. Explain the function of the air-chamber in a force pump.

9. A house usually settles after being built. If rigid iron service pipes are used, how can the effects of settling be avoided?

10. How are service pipes protected from frost?

11. How many square feet of grate surface will be needed to raise 150 gallons of water per hour from 45 degrees to one of 160 degrees?

12. What rules should be observed in making bends in pipes?

13. What are the salient features of the direct system of supply?

14. Explain the working of a common suction pump. Illustrate by diagram.

15. Name and describe five kinds of gas burners for lighting purposes.

16. When is a lift pump necessary? How does it differ from an ordinary suction pump?

GENERAL INDEX

GENERAL INDEX

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